DISCOVERY

The Little Owl (see R. S. R. Fitter's article)

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Physics

DISCOVERY

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The Progress of Science

The Origin of Life

A FEW decades back it was possible to maintain that the origin of life was an unexplained mystery. And many obscurantists made an unwarranted extrapolation to deduce that it was not only unexplained, but inexplicable. Today the origin of life is still unexplained in the sense that no explanation of it can be given which is based on sufficiently good evidence to receive the universal assent of scientists. But it would be presumptuous for anyone now to assert that the matter is inexplicable; for it is possible today to put forward explanations which are at least plausible and which may, in a crude way, represent the outline of the truth. If no more can be done, at least the problem can be stated in a way that reduces it to a search for certain physical and chemical phenomena whose general nature can be fairly clearly outlined. Physics and chemistry have been working their way upwards towards larger and more complicated structures, while biologists have made similar progress downwards. The two forces have not yet met, but their approach to one another is close enough to make possible well directed speculations about the no man's land between them, and thence at a further remove about the historical origin of life. One of the latest contributions is Professor J. D. Bernal's Guthrie Lecture, published in the *Proceedings of the Physical Society* (*A*, Vol. 62, part 9). It seems to us to be the most interesting contribution since the appearance of Schrödinger's book, *What is Life?*

To begin with, it is difficult enough to decide what is meant by 'life'. Bernal prefers not to attempt a rigid definition, but simply to note two main characteristics common to all known life, and to define life for the purposes of the discussion as any self-perpetuating system which possesses these characteristics. The first is that all life is based essentially on materials belonging to one class—the proteins. The second characteristic is the general nature of the chemical processes going on in living things. Laboratory or industrial chemical processes usually involve large energy jumps and large temperature changes. Living matter executes the same processes by dividing them up into many steps; each step is carried out with the aid of a catalyst—an enzyme, which is essentially one of the proteins; and as a result the energy changes involved in each step are small and virtually constant temperatures are maintained. The problem of the origin of life, therefore, reduces to that of discovering how out of a purely inorganic background there could have arisen assemblages of proteins having these chemical characteristics.

The way in which the elements sorted themselves out on the earth before life began can be traced with a fair degree of certainty. The most obvious difference, of course, would be the complete absence of elementary oxygen from the atmosphere, since our atmospheric oxygen is itself the product of plant life. The story must begin with an atmosphere of hydrogen, and such simple hydrogen compounds as methane, ammonia, hydrogen sulphide and water (in the form of steam). The earth's surface consisted mainly of molten silicates, with much water and carbonates in solution. The crystallisation of the crust must have forced out into the atmosphere vast amounts of water vapour and carbon dioxide. And at the same time hydrogen would be continually lost from the upper atmosphere, because the gravitational pull would not be strong enough to hold it. These changes would have led to a steady oxidation of the atmosphere; the methane would pass through several stages to carbon dioxide and water; the ammonia would be oxidised to nitrogen and the hydrogen sulphide to sulphur. By the time the earth was cool enough for water to condense, the atmosphere may have consisted largely of nitrogen and carbon dioxide. The sea would now contain mainly ammonia, carbon dioxide and hydrogen sulphide in solution.

Nowadays ozone in the atmosphere absorbs the greater part of the very energetic ultra-violet radiation from the sun. But in the oxygenless atmosphere of the days before life, there would also be no ozone, so that the earth's surface would have been exposed to powerful ultra-violet radiation. In this radiation Bernal sees a possible explanation of the first step towards the origin of life. What exactly would happen in the weak solution of ammonium carbonate and sulphide, of which the sea consisted, under the action of this radiation has not yet been experimentally determined. But it is extremely likely that processes of polymerisation and condensation (the joining of smaller molecules to make larger ones) would take place, leading

to the formation of nitrogenous organic compounds such as amino-acids. And amino-acids are the prefabricated units from which proteins are built. We have thus taken one step towards living matter.

It is easy to visualise a set of further chemical reactions which would build the amino-acids up into proteins—but not in the ocean where the drama has so far been enacted. The dilution would be too great for such a synthesis to be effective, and we must, therefore, seek for some mechanism capable of concentrating the substances concerned. Bernal finds a possible answer in the properties of clay. X-ray analysis and the electron microscope have shown that clay takes the form of piles of minute plates, each plate being about 10 Ångström units thick and about 140 Ångström units across. (A hundred million Ångström units equal one centimetre). The plates are capable of absorbing a large variety of organic substances at their surfaces, that is, of attaching molecules of these substances to their surfaces by means of forces that are weak compared with the forces inside the molecules themselves. They could absorb the amino-acids and other organic substances which (at the stage we are now considering) had been built up under the influence of ultra-violet radiation, thus concentrating them and placing them in a favourable position for the promotion of further molecule-building. Furthermore, molecules absorbed on clay surfaces are not attached at random, but in definite positions relative both to the clay and to each other; the tying-down of the molecules to set positions would make it easier still for them to undergo a further building-up process.

There is some indirect evidence in favour of the theory that the first proteins were formed in this way. If they were in fact built up from simpler organic molecules on the surfaces of clay particles, then we might expect the protein molecule of today to carry some traces of the clay plate on which it was 'moulded'. And in fact it seems that even the most complex proteins can be considered as based on a 'primitive protein molecule' in the form of a disk (itself composed of parallel groups of chains of atoms) about 10 Ångström units thick and from 30 to 60 Ångström units across. These dimensions are near enough to those of the clay particles to make it at least plausible that the latter provided the scaffolding upon which the first proteins were built. The self-reproducing properties of proteins, of course, are such that we might expect features of the very first models to be preserved in their most advanced descendants today.

The next step seems to have been based mainly on mere increase of size. Once protein molecules reach sizes larger than about 100 Ångström units, new types of forces which act at long range become significant. These are not mysterious creations out of nothing; they exist for all molecules, but at smaller sizes their effect is masked by the random motions of the molecules. The action of these forces has been observed in viruses, which are essentially protein molecules. The tobacco mosaic virus, for example, consists of rod-shaped protein particles; when in solution these tend to space themselves out and form a definite pattern. This is a simple case, but it does demonstrate the general point that when protein molecules reach a certain size they tend to lose their independence and begin to be organised into a certain loose unity. The unity might have varying degrees of complexity, involving one or many different proteins. The pattern of protein molecules thus produced might or might not be of a type which promotes and catalyses those sequences of chemical reactions which characterise life (or sequences sufficiently like them). No doubt the result was usually quite different, but given time the right pattern would eventually be produced.

At this stage it is reasonable to say that life has started, though it would still be a much more elementary and much less stable thing than even the simplest life of today. There would be no living organisms, for these protein groupings would still be far from possessing the individuality of organisms; they would be simply undifferentiated lumps of living matter possessing in rudimentary form the chemical properties of life. They would have the power of producing chemical changes through a series of small steps involving small energy changes, and thence the power to assimilate suitable materials from the environment in order to grow and perpetuate the system. But in doing so they would depend on further supplies of those simpler organic molecules from which they were built in the first place. In particular it would only be by using up these simpler molecules that they could obtain the energy with which to continue 'living'. Thus the new 'life' would quickly eat up the stores of simpler compounds so laboriously built up by ultra-violet radiation and concentrated by clay. When these were consumed, it would have no means of continuing; it would die for lack of fuel. Perhaps this primitive life started anew many times and burnt itself out many times. At this stage life, then, was doomed to undergo a series of creations and extinctions until some lump of living matter chanced on another mode of collecting energy—namely by photosynthesis, or the process associated with green plants whereby organic compounds are built up from carbon dioxide and water using the energy supplied by visible light.

Photosynthesis leads to the production of oxygen. With oxygen in the atmosphere life could become chemically very much as it is today. That is, energy would come in the first place from solar light, but it would then be stored in suitable chemical form, and the energy for use would be obtained by the oxidation of sugars or other suitable compounds. The production of oxygen would have the further effect of closing the door to any further spontaneous generation of life—for (if the theory is correct) this depended on ultra-violet radiation which would now be cut off by the ozone that must occur in an oxygen-laden atmosphere.

Much of this theory is speculation, and Professor Bernal only goes as far as calling it a "first crude attempt" on the problem. But it is notable in that some of the steps he postulates could be investigated experimentally.

Artificial Auroras

PUBLICITY has been given recently to a proposal made by Professor V. A. Bailey of Sydney University in Australia to create an artificial aurora by means of radio waves and so, perhaps, provide a source of general night illumination over a wide area. Two main problems can be discerned here: (1) the mechanism of energy supply from radio waves; (2) the mechanism of the production of visible light in the upper atmosphere.

The first problem has been taken up again by L. G. H

Huxley and colleagues at Birmingham University. The fundamental theoretical work was done by Bailey some fifteen years ago in connexion with the so-called Luxembourg effect produced when a listener tuned to Radio Luxembourg heard also the modulation from Radio Paris superimposed on his wanted signal. The effect was noticed with other combinations of signals and has since been renamed Wave Interaction, and is a phenomenon associated with the behaviour of waves passing through the ionosphere. When wave A is being absorbed and refracted in the ionosphere its electric field affects the electrons and gives them extra energy of vibration at its frequency. When wave B is absorbed and refracted in the same region of the ionosphere, this extra energy is added to B, which then proceeds downwards with the added modulation from wave A. Bailey developed an expression in 1934 and 1937 for the depth of impressed modulation in terms of the power and modulation depth and frequency of the interfering wave, the frequency* with which electrons collide with the gas molecules or atoms around it, and an expression for the loss of energy of an electron by collision. In a complete theory of such wave interaction an important quantity is the power given to a free electron by a high-frequency alternating electric field. An expression for this was developed by Bailey and by Huxley in 1937. The maximum interference effect is expected to be produced, as the result of a kind of resonance effect, when the frequency of the interfering wave corresponds to that imposed on the electrons by the magnetic field of the earth. This is called the *gyro-frequency*. Since the war Huxley and his colleagues, working in co-operation with engineers of the B.B.C., have verified the theory experimentally and their work continues.

Professor Bailey has now taken up the work again. The essential features of his experimental method can be briefly described. Radio waves transmitted from Brisbane are to be reflected in the ionosphere at or near Armidale, about half-way between Brisbane and Sydney. At Armidale a radio signal which will interfere with the Brisbane signal is to be shot upwards at the ionosphere. Physicists at Sydney will receive the reflected Brisbane signal, and examine the extent and nature of the interference that has occurred. The power of the Armidale beam is to be from one to two kilowatts and transmitted from a single horizontal aerial. The frequency of the gyro-wave is about 1500 kilocycles. The cost of this initial experiment is 2000 Australian pounds and has been met by the Federal Government.

Eventually it is intended to repeat the experiment with a power of a million kilowatts; this will require a large array of aerials, for which more money will be needed. It is thought that this vast power may make it possible to produce an artificial aurora.

This is a highly speculative project, as one would expect since all the experts are extremely cautious when it comes to offering an explanation of how natural auroras are produced. Professor Sydney Chapman, one of our most authoritative geophysicists, stated in 1948 that the task of developing an adequate aurora theory was "hazardous as well as extremely complicated". There is no universally accepted theory covering all auroral phenomena. An immense co-operative effort is being made by scientists—

*This collision frequency varies with temperature and pressure.

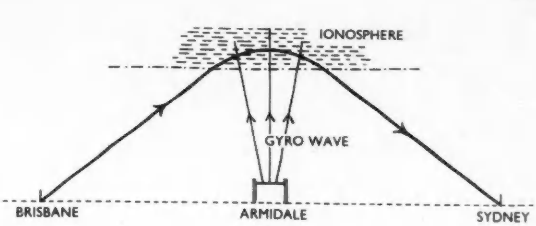


Diagram of Professor Bailey's present experiment. The interfering wave at gyro-frequency is shot vertically upwards at Armidale from a single horizontal aerial.

physicists, chemists, geophysicists, radio engineers, meteorologists—to arrive at an agreed corpus of facts on which a general theory can be based. Seen in this light, Professor Bailey's experiments should add useful data to the common pool.

The production of an artificial aurora, however, is another matter. The two most widely accepted theories of auroras agree that streams of positively ionised particles sweep out from the sun and drag in electrons in the process and thus the resultant stream of particles moving towards the earth is neutral as a whole. The stream approaches at a speed of the order of 1000 kilometres a second. When it gets within the earth's magnetic field it is swept up towards the magnetic poles—to put the matter in an over-simplified way. The interaction of the fast-moving particles and the atoms and molecules of gas in the upper atmosphere forms a huge factory for transforming the energy of impact of the corpuscles into radiation, much of which is in the visible part of the spectrum. The latter constitutes the light seen in auroral displays. These are seen towards the magnetic poles and vary very much in intensity and quality. In addition there is a slight emission of light that is comparatively constant and is usually called 'night-sky' emission; this faint illumination is visible on most clear moonless nights, and is thought to be produced in a similar way to the aurora. (Night-sky emission is also often called 'auroral light'; those who favour the latter term speak of the more sensational displays as 'polar auroras'.)

The available facts suggest that Professor Bailey expects to produce eventually a glow or 'night-sky' emission, though some of the publicity given to the project recently has not made this clear. The effective energy in natural auroras is supplied by charged particles in great numbers moving at 1000 kilometres a second or thereabouts. The effective energy in Professor Bailey's experiment is to be supplied by electrons whose energy has been stepped up by means of an incident radio wave at the gyro-frequency. It is obvious, therefore, that the precise quantitative relationship between the energy of the radio wave and the extra energy in the electrons is very important, and it still remains to be seen whether these electrons have enough energy to cause light, even of the feeble magnitude seen in night-sky emission. It may be that the initial experiment will give enough information to enable Professor Bailey to decide whether his hypothesis is worth following up.

One final point—even if the proposed scheme produces light, it will be most effective only on cloudless nights.

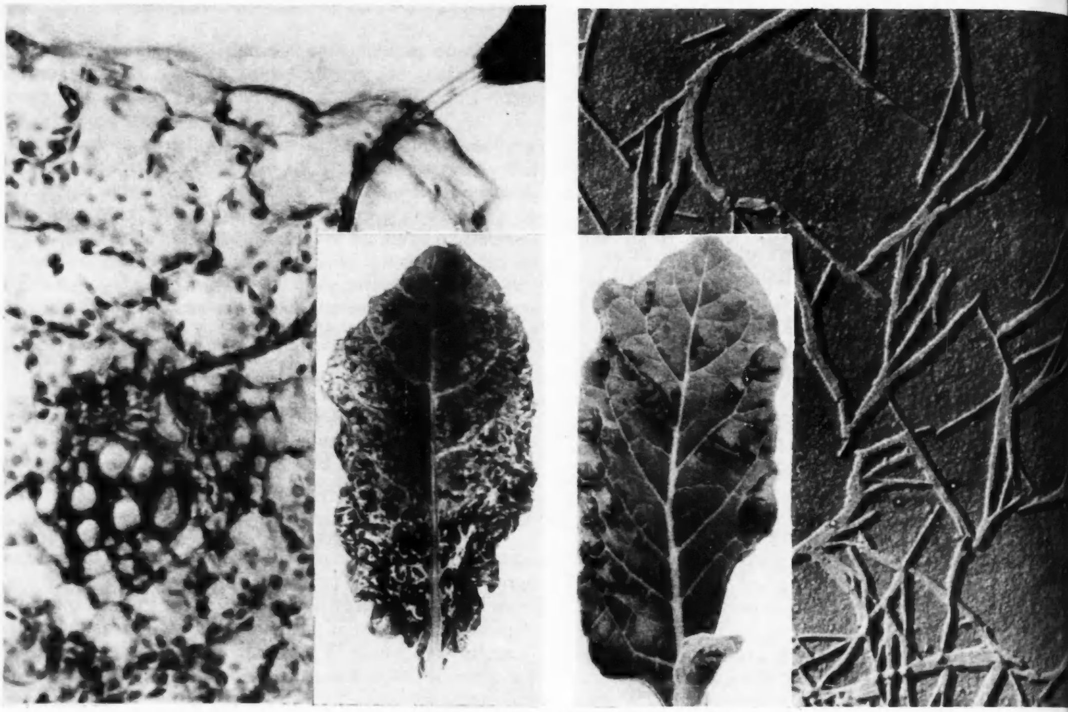


FIG. 1 (*left*).—Many plant viruses are transmitted by aphids. This photomicrograph shows how an aphid feeds; the insect is tapping nutrient liquor from the vein of a sugar beet leaf. (*Photo by Rothamsted Experimental Station.*) Fig. 1a (*inset*) shows a sugar beet leaf infected with aphid-borne mosaic disease. FIG. 2 (*right*).—Electron microscope photograph (*by Williams and Wyckoff*) of particles of tobacco mosaic virus, symptoms of which are seen in FIG. 2a (*inset*).

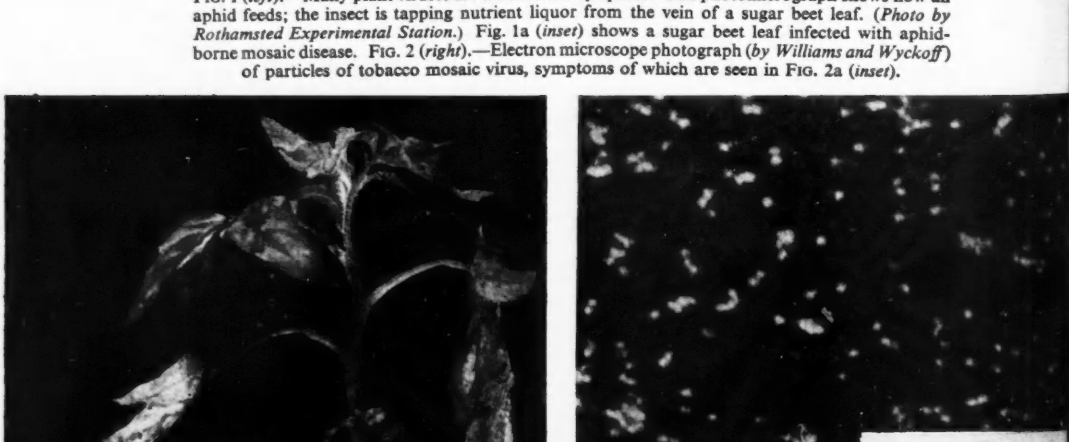


FIG. 3 (*left*) and 3a (*inset*).—A tomato seedling killed by tomato bushy stunt virus; and photomicrograph showing crystals of the virus. FIG. 4 (*right*) and 4a (*inset*).—Particles of turnip yellow mosaic virus, and a leaf of Chinese cabbage infected with this disease.

Plant Viruses and Agriculture

KENNETH M. SMITH, F.R.S.

CROPS, like man himself, are subject to attack by many different diseases caused by several different types of disease agents and such diseases, we are frequently told, involve losses of millions of pounds every year. But these losses, like the deaths on the roads, have been accepted for many years with equanimity. Now, however, with a world food shortage and with warnings that food production must be increased by 110% in the next ten years to keep up with the birth rate, we are going to be compelled to do something about it.

Infectious diseases in plants, as in man, may be due to such micro-organisms as bacteria or fungi or to the so-called ultra-microscopic viruses. It is with these last that we are concerned in this article.

Now it is necessary to understand a little of what is meant by the terms 'ultra-microscopic' or 'filterable' viruses and how these agents differ from microscopic organisms like bacteria, because on these differences may be based important methods of control or eradication. The term 'filterable virus' arose from an experiment carried out in 1892 by a Russian botanist, Iwanowsky, who showed that the sap from a tobacco plant infected with the 'mosaic' disease was still infectious to healthy tobacco plants after it had passed through a filter, the pores of which were too fine to allow any bacteria to pass. This experiment, incidentally, was the first scientific demonstration of the existence of a virus.

Viruses were called 'ultra-microscopic' because as a whole they are too small to be resolved with the ordinary microscope which uses visible light. Now, however, both terms are obsolete because filters can be made from collodion with pores fine enough to hold back viruses and even to separate virus mixtures, and the smallest plant viruses can now be seen and photographed by means of the electron microscope (Figs. 2–4). Nowadays, therefore, we use the word 'viruses' without either qualifying adjective.

So one characteristic of viruses is their extremely small size; some are so small as to be of molecular size. Furthermore, viruses have some characteristics of what we call living organisms, in that they can reproduce themselves and also mutate, that is to say, change their form slightly, and some characteristics more reminiscent of chemicals because certain viruses have been purified and isolated in a crystalline form. But there are other characteristics of viruses more directly concerned with the object we have in view in this article, the elimination of virus diseases, and one of the most important from this aspect is the way viruses get about.

Now, many of the micro-organisms produce spores and these resting bodies may be distributed in a variety of ways, notably by the wind, so enabling the organism to spread from plant to plant. But viruses are much more efficient parasites than that; instead of relying on such an uncertain mode of transport as the wind many viruses are carried direct to the right kind of plant and injected straight into the right kind of tissue by the finest hypodermic needle in the world, the sucking mouthparts of aphids and similar insects.

The relationship between plant-feeding insects and the viruses they carry is an interesting and complicated problem and all that can be said about it here is that not all insects are able to act as 'vectors', as they are called, of viruses but mostly those which feed by sucking the plant sap, such as aphids, leaf-hoppers and mealy bugs (Fig. 1) and not by biting the leaves. It will be understood from this, therefore, that the control of insect-transmitted viruses may also involve the entomological problem of how to control the insect vector, since, if that is eliminated, the virus cannot spread.

In studying a virus disease, therefore, with a view to its control, one of the first and most important things to be done is to find out how it spreads and, if it is insect-borne, to identify the particular insect concerned which is by no means always easy. For example, many years elapsed before it was discovered how a virus disease of the peach tree in the U.S.A., known there by the peculiar name of the 'phoney disease', was spread from tree to tree. Now we know that it is one particular kind of sap-sucking insect which transmits the virus. Similarly, much painstaking research was necessary to identify the insect vector of the 'swollen-shoot' disease of the cocoa tree and as for the so-called spike disease of sandal in India, it is still not certain what insect, if any, out of the many associated with sandal is responsible for the spread of the disease.

Another characteristic of viruses is that they are unable to reproduce themselves outside a living susceptible cell. This is quite unlike many micro-organisms which can be grown on an artificial medium such as a nutrient jelly in a test tube. So now we have some idea of the main characteristics of plant viruses; they are excessively minute disease agents which cannot be seen with the ordinary microscope; they cannot multiply outside a living cell, and they are dependent in many cases on particular insects to transport them from plant to plant.

In addition to the plant viruses, there are of course other viruses which attack animals of all kinds including man and some of these, such as the yellow fever virus, are also insect-borne.

More than 150 distinct viruses are known to attack plants and many cause diseases of great economic importance. Potatoes, especially in the southern half of England, suffer from several virus diseases, such as mosaic and leaf-roll (Fig. 5), and these may cause a heavy drop in the yield, sometimes reducing the crop by 50%. One particular potato virus, known as potato virus X, has been calculated to reduce the world's crop of potatoes by 10%. The losses of potatoes in Britain alone, due to virus infection, have been put at one million tons per annum. The extensive trade in 'seed' potatoes totalling over half a million tons, which takes place between England and Scotland every year is due entirely to the prevalence of virus infection in England.

Sugar beet is another agricultural crop which suffers severely from virus diseases; in this country there are two main viruses attacking the sugar beet, causing *mosaic* (Fig. 1a) and *yellows* respectively. The latter is the more serious disease and, if the crop is infected early in the

season it may cause a loss of 50% of the sugar content. Other crops in Britain which are affected with virus diseases are strawberries, raspberries, hops, brassica crops, beans and flowering plants of all kinds. In the U.S.A., in addition to most of the viruses found in Britain, there are the diseases known as *curly-top* of sugar beet and *yellows* of asters. Both the viruses causing these diseases have a wide host-range and give rise to serious infections in many other crops. In tropical regions there are several important virus diseases, the best known and most topical of which is the *swollen-shoot* disease of cocoa. The tea plant is also subject to a virus disease known as *phloem necrosis* which gives a brown discoloration internally, caused by the dead phloem cells. In addition to this internal symptom, there is also a bending and curling back of the leaves along the midrib.

Groundnuts which are much in the news at the present time are liable to attack by an aphid-transmitted virus causing a disease known as *rosette*.

A serious situation has arisen in the clove industry in Zanzibar where the clove trees have been dying in large numbers. The disease which causes the sudden collapse and death of vigorous trees has been called the *sudden death disease* and by a process of elimination of all other possible causes is now considered to be due to a virus. Its mode of transfer does not yet appear to be known.

Now, in trying to reduce the great losses caused to our crops by virus diseases, to say that prevention is better than cure is an understatement, because, apart from a few exceptional cases to be referred to later, there is no cure of a virus-diseased plant. So that most of the methods of control of plant virus diseases are *preventive* measures designed to avoid or ward off infection from the plant. Spraying a plant which is once infected with a virus disease is useless so far as any curative effect is concerned though spraying which is directed against the insect vectors of a virus may be helpful in some cases.

Starting with a Virus-free Crop

Virus diseases are of fundamental importance in crops which are vegetatively propagated for the following reason, viruses are always transmitted by means of tubers, runners, cuttings, etc., if the plant from which these are taken is itself virus-infected. This fact is well illustrated by the potato plant. If the parent plant is virus-infected then the tubers from it will give rise to virus-infected plants. Because potato viruses are so widely distributed in England and because the aphid vector of the important potato viruses is so prevalent, it is useless to save 'seed' potatoes from crops grown in most parts of England. It is for this reason that the English farmer buys his 'seed' potatoes afresh each year from Scotland or Ireland where the virus infection is much lower, chiefly owing to the absence of the aphis vector. A similar situation exists with strawberries and raspberries, many of the well-known varieties are heavily infected with viruses so that propagation from them becomes unprofitable.

How then, if in such cases the parent stocks are full of virus, is one to start with a virus-free crop? It can be done by building up a stock of virus-free plants by means of careful selection and scientific testing for the presence of viruses. Once such a stock has been obtained it is kept isolated, so far as possible, from virus infection and propagation is made only from such virus-free stocks. An attempt on these lines has been made at Cambridge to build up stocks of virus-free potatoes. The first stocks consisted of a few plants of each of the popular potato varieties which careful testing had shown to be free of virus. These were the foundation or nucleus stocks grown in an insect-proof glasshouse, and each year a quantity of tubers was planted out-of-doors in as complete isolation as possible. At first they were grown in Ireland by a competent farmer who specialised in growing seed potatoes but latterly they have been propagated on an island off the coast of Scotland. From time to time samples of these potatoes which are being grown out of doors in isolation are returned to Cambridge for testing as to virus content. On the whole they have remained remarkably free from virus infection. The object in view is to build up a large supply of really virus-free potatoes which will then be gradually fed back into the seed potato trade thus helping to reduce the number of virus-infected tubers.

One or two enterprising farmers are doing this for themselves by growing the first nucleus stocks in a glasshouse, testing them for virus and multiplying up their virus-free stocks in isolation. It should, of course, be realised that such potato stocks are only *virus-free*, not *virus-resistant*.

Some such scheme is badly needed by the dahlia industry because the dahlias of this country are heavily infected with virus diseases and being, like the potato, vegetatively propagated, the viruses are passed on from year to year. It would probably pay each dahlia grower to select, by inspection, a stock of plants free from the leaf mottlings and distortions characteristic of virus infection and propagate only from these, keeping them as far apart as practicable from all other plants.

Curiously enough very few viruses are carried in the seed of infected plants so that where the new crop is raised from seed, as for example with sugar beet, it is easy enough to start with a virus-free crop. The difficulty there is to stop the arrival of the virus in the sugar beet and its subsequent dispersal about the crop. This brings us to the question of dealing with the insect vectors of viruses.

There are two aspects of this problem, first a direct attack on the insects and secondly attempting to avoid or circumvent them. Up to the present not very much success has been achieved in controlling a virus disease by attempting to eliminate the insects which spread it, although better results are likely with some of the new insecticides.

The main difficulty lies in the fact that not many insects are required for the spread of a virus and with some viruses a feeding period of a few minutes is time enough for the insect to pick up and distribute the infection. It is the mobility of the insects which is probably of greater importance than their numbers; an active insect will bring the virus into the crop and then distribute it to healthy plants within the crop. Large numbers of wingless aphids which remain more or less quiescent on one or two plants are obviously less important than a few winged individuals which may rove over the crop distributing infection wherever they go.

Although, as already pointed out, direct attacks on the insect vectors have not, so far, brought much success, there are special cases where this method has given a certain

FIG. 5.—Leaf-roll is a serious disease of potatoes. Compare the condition of the infected plant with the leaves of the healthy plant at top left.
(*Photo by Roy Markham*).

amount of control. For example, in the case of the virus diseases of the sugar beet, a common source of infection is the seed or 'mother' beet which overwinters and is frequently infected with virus. Destruction of the aphids on the *steckling* beds by *repeated* dusting or spraying with nicotine helps to reduce infection.

Similarly with the aphid-borne viruses of strawberries, a certain amount of control of these diseases has been achieved by nicotine fumigation of the strawberry plants in the field by an ingenious technique whereby nicotine vapour is pumped into a low canvas tent towed slowly over the crop.

One of the drawbacks of using some ordinary insecticides is their indiscriminate effect on all insects, harmful and beneficial alike, but this does not apply to the so-called systemic insecticides which are selective in that they destroy only the insects which feed on the plant and not the beneficial parasites which prey on the plant-feeding insects. Systemic insecticides are taken up into the tissues of the plant and any insects feeding on the plant, particularly aphids and similar sap-sucking insects, ingest the poison and are killed. There is some hope that with the development of systemic insecticides better control of insect-transmitted viruses may be achieved.

By carefully selecting the site and time of planting a crop it is sometimes possible to avoid the insect vectors of a virus. A good example of this, on a large scale, is afforded by the growing of 'seed' potatoes in those parts of Scotland where the chief insect vector of potato viruses, the aphid *Myzus persicae*, is scarce or absent.

By careful study of its life-history and habits one can do something, even in England, to avoid this aphid. For example, it is known that *Myzus persicae* overwinters in three possible ways, inside heated glasshouses where it continues to reproduce throughout the winter, as a winter egg on peach trees out of doors and in mild winters as an adult on brassica crops. Bearing in mind these facts it is sometimes possible to choose a site which avoids all three contingencies.

Early sowing of a crop, such as sugar beet for example, will sometimes avert an infestation of aphids until the plants are larger and better able to withstand attack. In the case of a particularly valuable crop or with young susceptible seedlings, a more positive method of avoiding the insect vector is to ward it off the plants by means of a screen or cloth cage. The screen has been used in the U.S.A. to keep off the leaf-hopper which transmits the virus of asters causing 'yellows' but it was found more efficacious to grow the plants inside a cloth cage. This latter method has also been used to grow virus-free seed potatoes in isolation and to protect them from insect-borne viruses.

The sources of virus infection can be very varied and include plants growing from potato tubers or sugar beet overlooked from the previous year's crop. These 'groundkeepers' as they are called, are frequently infected with viruses and are particularly important as sources of infection.

The elimination of weeds and other wild plants which may act as hosts for a particular virus is important if they can be identified but this is not always easy. It is sometimes unwise to grow certain crops in close proximity to each other. A good example of this is to grow field beans and peas close to clover. The latter being a perennial plant is invariably infected with several aphid-borne viruses which usually do not have a very adverse effect on the clover plant. On beans and peas, however, the effect of these viruses is very much more severe. In this case not only is the clover crop a source of virus infection for the beans and peas but, since it is also the winter host of the main aphid vector of these viruses which migrates to beans and peas in the spring, conditions are ideal for the dissemination of the viruses.

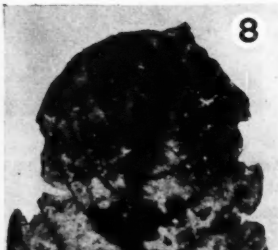
Cutting out or 'roguing' the infected individuals in a

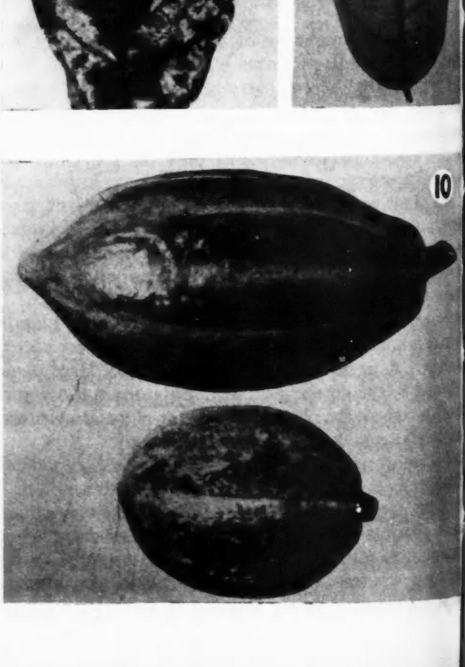
SWOLLEN SHOOT DISEASE

The future of the cocoa industry is threatened by Swollen Shoot Disease, which has killed thousands of cocoa trees in Africa. FIG. 6.—A cocoa tree completely dead from this disease. FIG. 7.—These photos show swellings symptomatic of infection by Swollen Shoot virus, and the way it causes the leaves to die back. FIGS. 8 and 9.—Another symptom is the yellow mottling of the leaves; a healthy leaf is shown on right. FIG. 10.—Healthy and diseased cocoa pods.

Fig. 6.—*Photo. by J. Nichol.*

Figs. 7–10.—*Courtesy, West African Cacao Research Institute.*





crop is sometimes the only method of tackling a virus disease. The application of the 'cutting out' method on a large scale is being carried out at the present time in an effort to control the very serious virus disease of the cocoa tree, which is known as 'swollen-shoot' because one of the characteristic symptoms is the production of the type of swelling shown in Fig. 7. Unlike most plant virus diseases, this one seems to be invariably fatal and affected trees die about twelve months after the onset of the disease (Figs. 6–10).

The swollen-shoot disease of cocoa has been much in the news lately, not only because, in the words of Lord Rennell, "the cocoa industry of the Gold Coast is within measurable distance of extinction unless remedies are applied at once," but because of the riots at Accra which were directly connected with swollen-shoot and the measures being taken to stamp it out. This virus disease in the Gold Coast probably started about 1920, although it was not till 1936 that reports were received that cocoa trees were 'dying back'. At first there seemed to be only a few acres affected but soon reports were received from many areas that the disease was spreading and 10,000 trees were known to be dying. Up to 1939, trees were dying at the rate of one million a year. The annual rate between 1939 and 1945 was five million and between 1945 and 1948 it rose to fifteen million. At this rate it is clear that the cocoa industry of the Gold Coast will soon disappear. Meanwhile attempts were being made to find out what was causing the disease and scientists were sent out to investigate the trouble. At first, various explanations were put forward; a fungus was supposed to be the culprit. When that was disproved, the suggestion was made that the trouble was physiological and not parasitic. The cultural conditions were said to be unsuitable and the die-back was due to lack of shade. So numerous shade trees were planted but the disease continued to spread and cocoa trees growing in the the shade were just as much affected as those out of it. Then in 1940 the research station at Tafo discovered that swollen-shoot was infectious and could be transmitted to healthy trees. This showed that a virus was the cause, there being no visible disease agent present, and an intensive search was made for the insect vector. By the rate and method of progress of the disease it was fairly obvious that some insect or other was spreading it and this was finally identified as one or more species of mealy bugs, an insect with sucking mouthparts related to the aphid or greenfly.

By this time it was realised that cutting out the infected trees was the only method which would stop the progress of the disease. So that in January 1947, cutting out on a compulsory basis was introduced and during the next twelve months about two and a half million diseased trees were cut out. After this, however, resistance on the part of the farmers to the cutting out developed and rioting and violence brought these measures to a close.

In order to convince the farmers and others on the Gold Coast that the cutting out policy was based on necessity and was not a political stunt, a Commission of three foreign scientists paid a visit of inspection to the cocoa plantations. They were unanimous in support of the cutting-out policy, advocated by the local investigators, and even suggested an intensification of it. So now the process of eliminating the diseased cocoa trees has started again and up to the middle of the summer 1949 six million trees had been cut out and the process is continuing at the rate of 350,000 a month. Time will show whether these efforts will be successful or if it is another case of 'too little and too late'.

There is a further factor involved in the spread of 'swollen-shoot' and that is the presence of wild plants which may harbour the virus. These have already been identified by the workers at Tafo and two of them have been found to be among the biggest of the forest trees. So that elimination of these is going to be a difficult problem.

Breeding Virus-resistant Plants

The production of a virus-resistant variety of a susceptible plant is a piece of long-range research but nevertheless it is to the plant breeder that we must look for substantial help in the matter of the control of plant virus diseases. A good deal has been achieved already, notably in the U.S.A. with regard to sugar beet resistant to the curly-top virus. Other examples are a variety of cotton resistant to the leaf-crinkle virus and sugar-cane varieties resistant to mosaic. In Great Britain efforts are being directed towards the production of potato varieties which are resistant to the more important of the viruses to which the potato in this country is liable.

Resistance or immunity to virus disease in plants may be based on quite different properties of the plant in question. For example, one plant variety may be resistant to infection because the leaves are hairy and so the plant is avoided by the insect vector and thus escapes infection. Another type of immunity is the rather anomalous one of extreme susceptibility. Some potato varieties are what is called 'field immune'; this means that the plant is so susceptible to the virus that it is killed outright and the virus is destroyed with its host and so cannot spread. It may be asked in that case why the swollen-shoot virus is not also self-eliminating. The answer is to be found in the time factor; the potato plant dies rapidly, and if it is a question of a certain aphid-borne virus, the insect refuses to feed upon the affected leaves which quickly become unpalatable. In the case of the cocoa tree the dying process is naturally much slower and there is ample time for movement of the insect vector among affected and healthy trees.

A third type of resistance is found in the reaction of the plant to infection with certain viruses. For example, when a close relation of the tobacco plant, *Nicotiana glutinosa*, is infected with the tobacco mosaic virus, the virus is localised in spots surrounded by dead cells from which it cannot escape and infect the whole plant (Fig. 11). It may be recollected that one of the characteristics of a virus is that it can only multiply in a living cell; so that in this case it cannot move through the encircling barrier of dead cells. The plant breeder has taken advantage of this localising property on the part of the plant and attempts, at least partially successful, have been made to transfer the gene responsible for this localisation of virus to plants of economic importance such as tobacco and pepper. The practical result of this is that the virus not only cannot spread from the leaf through the plant but, still more important, cannot spread from plant to plant.

In the case of diseases of animals it is frequently possible to stimulate a resistance or confer a temporary immunity to a given disease by inoculating the subject with a preparation of the disease agent itself which has been altered in some way. Vaccination against smallpox is the classic

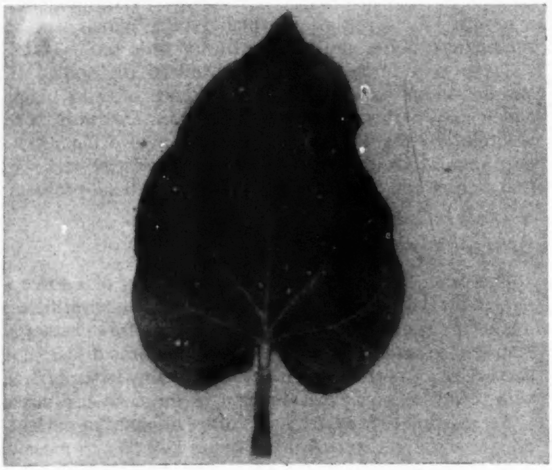


FIG. 11.—A leaf of a plant (*Nicotiana glutinosa*) which reacts to infection with tobacco mosaic virus with a local response only. The virus is imprisoned within a ring of dead cells and cannot escape to invade the rest of the plant.

example of this. The altered virus when injected into the body stimulates production of antibodies which confer immunity without inducing the severe disease itself.

It is sometimes asked why plants cannot be vaccinated in a similar way. The answer is because plants do not, so far as we know, have antibodies and so cannot develop this kind of acquired immunity. There is, however, another kind of acquired immunity developed by plants to certain virus infections and this may be worth a brief mention. One of the characteristics of viruses which is also a characteristic of living things is the power to mutate or change their form slightly, so that a virus may frequently occur in several related strains. Now this is where the acquired immunity comes in. A plant infected with one strain of a given virus is usually immune to infection with another strain of the same virus. If, of two or more strains of a given virus, one strain is very mild and gives rise to a comparatively innocuous disease then this strain can be used to 'vaccinate' the crop to keep out the commoner and more severe strain of the same virus. So far this method of control has been largely academic but it may be developed further in the future. For this type of vaccination, therefore, there are two essential requirements, first the virus in question must exist in more than one strain and secondly one of the strains must be avirulent, causing only a very mild disease in the plant.

Occasionally it is possible to cure a plant infected with a virus by the application of heat. This has only been done in cases where the virus has a very low thermal inactivation point or, to put it more simply, where the virus is destroyed by subjection to comparatively low temperatures which will not harm the plant. In the U.S.A. peach trees affected with several viruses have been cured by this heat treatment. The infected trees were kept at a temperature of 35°C. for a fortnight or more; the time necessary was longer for large trees than for small and it proved easier to destroy the virus in the top of the tree than in the roots. Sometimes a virus can be destroyed only in certain plants. For example, the virus of aster yellows can be eliminated from periwinkles (*Vinca rosea*) and *Nicotiana rustica*, but not from asters which could not survive the treatment which necessitated exposure to a temperature of 40°C. for two weeks.

Cure of virus-infected plants by means of chemicals, or chemotherapy as it is called, has not yet progressed very far. There has been one report from the U.S.A. of the elimination of a virus from peach buds by soaking them in certain chemicals, such as urea and sodium thiosulphate.

The problem of the control of plant virus diseases is sometimes complicated by the existence of plant 'carriers'. These are varieties or species of plants which may become fully infected with a virus but yet show no symptoms and from inspection alone would pass for perfectly healthy plants. Such plants are, of course, a source of virus infection to other non-carrying varieties. The phenomenon is to be found in a number of different crops and symptomless carriers are common in strawberries, raspberries, hops, potatoes and dahlias. The popular dahlia variety, Bishop of Llandaff, is a symptomless carrier of the cucumber mosaic virus.

Sometimes the lack of symptoms exhibited by a virus-infected plant is a function of the virus rather than of a particular variety of plant. This is true of the economically important potato virus X which exists in a number of strains, some of which produce little or no symptoms on any variety of potato. Now this state of affairs has serious consequences for the grower of 'seed' potatoes. In spite of the rigorous 'roguing' of any potato plant showing a leaf mottling, which is carried out by the Scottish potato inspectors, these symptomless strains of the virus X cannot be eliminated by inspection alone. It may be thought that as there is no disease, the presence of such a virus is not important but that would be far from the truth. Various experiments have shown that the yield of a potato crop may be reduced by as much as 10% by the presence of a strain of the virus X which gives no visible disease. So is there any test which will give a quick answer as to whether a potato plant is free of a symptomless virus X? Actually a quick test for the presence of virus is available but it needs to be carried out carefully. This is the serological test and whilst it cannot yet be used for all plant viruses, it is applicable to potato virus X. When a virus, the *antigen*, is injected into an animal, preferably a rabbit, *antibodies* are produced in the blood which react in an observable way with the specific virus injected and its *related strains* but not with any other virus. The reaction in question is to form a precipitate when the antiserum and the virus under examination are mixed in a tube and put in a warm water-bath. By this means it is fairly easy to determine whether a particular potato plant is infected with virus X, by mixing a little of the clarified sap with the antiserum to virus X and warming the tube in the water-bath to see if a precipitate forms. This test, of course, will not indicate whether any other virus is present, but then their presence in the potato plant is usually shown plainly enough by the symptoms evoked.

Readers will find further information on this subject in these two books by Kenneth M. Smith, "Beyond the Microscope" (a Pelican Book) and "Plant Viruses" (Methuen's Biological Monographs: 2nd edn., 1948).

Harnessing Fluorine

FREDERICK KURZER, Ph.D., A.R.I.C.

In the course of scientific work planned to solve a particular problem, unexpected obstacles are nearly always encountered which must be removed before satisfactory work on the main problem can proceed. Moreover, its eventual solution frequently throws fresh light on other questions, or provides new tools that may find much wider application and infuse new life into branches of science, which, for want of the right techniques, have been lying dormant for some time. It often happens, therefore, that a programme of research stimulates work in apparently unrelated fields and produces rapid progress in other, sometimes unexpected, directions.

Several examples of such situations occurred during the war-time Atomic Energy Project, which was aimed primarily at the manufacture of atomic weapons, but produced advances along many other lines. One consequence of this work is that radioactive isotopes, which had previously been obtained only with difficulty in limited quantities, have now become available in large numbers for biological and medical research. A rather less predictable consequence of atomic-bomb research has been the tremendous stimulus given to what had hitherto been a comparatively quiet back-water of scientific inquiry—the study of fluorine. Because of the difficulties and hazards involved in handling this dangerous material, the chemistry of fluorine had previously received attention from comparatively few workers, and with one or two exceptions, their investigations were mainly of academic interest. In these early researches several of the courageous pioneers like Thenard, Gay-Lussac, and Davy suffered severely from the toxic effects of hydrofluoric acid, and the results of fluorine-poisoning actually sent the Belgian chemist Louyet to an untimely death.

When the necessity arose, in 1941, for separating large quantities of uranium into its isotopes, a compound of this metal was required that could be fractionated by the gaseous diffusion process. It was soon realised that the form in which uranium could best be vaporised for this purpose was its compound with fluorine, namely uranium hexafluoride, UF_6. The sudden urgent demand for this substance resulted in a determined and systematic study of the chemistry of fluorine, both in this country and the United States. Uranium hexafluoride is one of the most reactive substances known and has a highly corrosive action on many materials from which chemical plant is constructed. The corrosive action of uranium fluoride depends on its ability to part with some of its highly active fluorine; this has a powerful tendency to enter the molecules of surrounding substances, which are thus made to undergo very profound changes. It is this 'fluorination' process which causes speedy destruction of metals and familiar every-day materials. The chemical engineers who had to design plant capable of handling uranium fluoride in quantity needed materials, from which vessels, pipes, and other apparatus resistant to uranium fluoride could be made. It is now known that, under carefully controlled conditions, fluorine and several of its corrosive derivatives can be safely dealt with in plant made from some of the metals ordinarily used in chemical engineering. In the earlier stages of the Atomic Energy Project, however, chemists had attacked the corrosion problem from a different angle, which had widened the fluorine research programme still further and led to the intensive investigation of the 'fluorocarbons'. These compounds are already saturated with fluorine and will not take up any more. They are therefore unaffected by fluorine and uranium hexafluoride. It was from among these materials that a solution was sought to the problem of finding suitable fluorine-resisting materials for constructional purposes and for use as lubricants.

The breath-taking speed with which this urgent problem was solved, and translated from the laboratory experiment to the large-scale process in the factory, makes this one of the most outstanding achievements in research and development. Preliminary experiments on fluorocarbons had begun in mid-1941, a large scale research programme was initiated in 1942, but work on some of the major chemical engineering problems was started only late in 1942. Nevertheless, the new fluorine-resistant materials had been produced in sufficient quantities by the time the first diffusion units for the separation of uranium were tested at Oak Ridge. These developments can best be appreciated if one knows the salient details of the story of fluorine from the time of its discovery some sixty years ago up to the present day.

The Preparation of Fluorine

Although the element fluorine is far too reactive to be found in nature in the uncombined state, its compounds with other elements occur abundantly and are widely distributed in rocks. The late discovery of fluorine and the comparatively slow initial accumulation of knowledge of its properties and potential uses was certainly not caused by any scarcity of fluorine in nature, but was entirely due to the exceptional difficulties that were encountered in handling this remarkable element.

Although fluorine-containing materials such as fluorspar (calcium fluoride) had been described in medieval times, many brilliant chemists, including Davy and Faraday, were baffled in their repeated efforts to isolate fluorine from them. Davy's attempts (1813) to electrolyse hydrofluoric acid, which is a corrosive, strongly fuming liquid, had been unsuccessful, and the account of his experiences can have offered no encouragement to later investigators. He wrote:

I undertook the experiment of electrising pure liquid fluoric acid with considerable interest, as it seemed to offer the most probable method of ascertaining its real nature, but considerable difficulties occurred in executing the process. The liquid fluoric acid immediately destroys glass and all animal and vegetable substances, it acts on all bodies containing metallic oxides, and I know of no substances which are not rapidly dissolved or decomposed by it.

In 1834, Faraday thought that he had obtained 'fluorine in a separate state' by passing an electric current through melted fluorides, but had to admit later: *I have not obtained fluorine. My expectations, amounting to conviction passed away one by one when subject to rigorous examination.*

No significant progress had been made by 1883, when the brilliant French chemist Henri Moissan began his now classical investigations. In the course of three years' hard work, during which one attempt after another had given disappointing results, Moissan returned to Davy's original method, the passage of an electric current through hydrofluoric acid. On electrolysing solutions of this acid in water, however, only the water was decomposed by the current, while pure liquid hydrofluoric acid would not conduct electricity at all. As so many times before, experiments seemed again to be doomed to failure; then, on June 26, 1886, Moissan made the dramatic discovery that the addition of a few fragments of the salt potassium hydrogen fluoride to the hydrofluoric acid rendered the liquid conducting. At last an electric current could be made to flow through the apparatus, and for the first time, bubbles of the elusive element fluorine appeared at the anode. To allow for the highly corrosive nature of the materials, Moissan built his first apparatus entirely from platinum, with the exception of the electrodes used for passing the current; these were made of an alloy of the noble metals platinum and iridium, but they were quickly eaten away and had to be thickened at the ends to make them serviceable. Even at the low temperatures, at which the process was operated ($-23°$ C), six grams of platinum were corroded for every gram of fluorine produced.

In subsequent years, various improvements were made in the process, but before World War II the production of fluorine remained a small-scale operation that was difficult to manage; the element was still a laboratory curiosity and was not available commercially. During the war, the sudden demand for fluorine compounds called for its production on a large scale, and the electrolytic method was

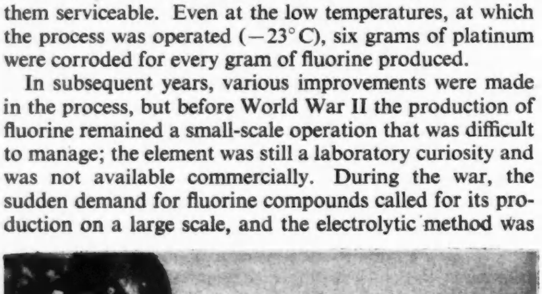


FIG. 1.—This 250-amp cell, capable of producing one-third of a pound of fluorine an hour, was developed in America. Commercial preparation of fluorine necessitated the perfecting of larger cells; British production rests on electrolytic cells with a 1000-amp capacity.

FLUORINATION OF A HYDROCARBON

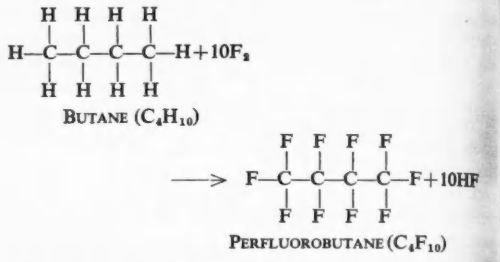


FIG. 2.—By substituting all hydrogen atoms in hydrocarbons with fluorine atoms, compounds containing carbons and fluorine only (so-called fluorocarbons) are obtained. The fluorination of butane is shown above.

successfully adapted to the manufacture of this element by the ton. The discovery, already foreshadowed by Moissan, that with absolutely dry hydrofluoric acid containing no trace of water the expensive platinum could be replaced by other metals or alloys was fully developed by teams of chemical engineers; electrolytic cells of steel or nickel containing massive carbon-electrodes capable of carrying the big currents that were necessary were designed and successfully operated. At the same time reliable techniques had to be evolved to minimise the hazards of handling and storing large quantities of fluorine.

Fluorine produces deep-seated burns on slightest contact with the skin, and severely attacks the eyes and the mucous membranes generally. Plant intended for the manufacture of fluorine had to be designed with unusual care to eliminate all possibilities of leakage. Although dry fluorine gas can be safely pumped through copper and other metal tubes, absolute cleanliness of all pipes and connexions is essential, since a speck of dirt or grease can initiate a combustion and may lead to severe explosions.

When it first began to be manufactured on a large scale during the war, it was the practice to use up all the fluorine immediately it was produced. The need was soon felt, however, for storing and transporting the gas, and safe methods for filling nickel cylinders holding 5 lb. of fluorine at a pressure of 400 lb. per square inch were worked out. Operations with fluorine flowing under ordinary pressure were known to require careful watching; precautions had to be increased when the highly compressed material was dealt with. Specially designed valves which required no greasing were employed, for fluorine under pressure quickly reacts with lubricants, and may cause a 'hot spot', at which further attack continues on the metal of the cylinder.

Fluorocarbons

Concurrently with the large-scale production of fluorine and the study of its properties, a great many fluorine-compounds were prepared; particular attention was given to 'fluorocarbons', which were expected to show extreme resistance to chemical attack, and which can be produced from hydrocarbons derived from petroleum.

Petroleum consists of a mixture of many different hydrocarbons, whose molecules are made up of *carbon and hydrogen atoms only*, combined together in various proportions and arrangements. The size and shape of the

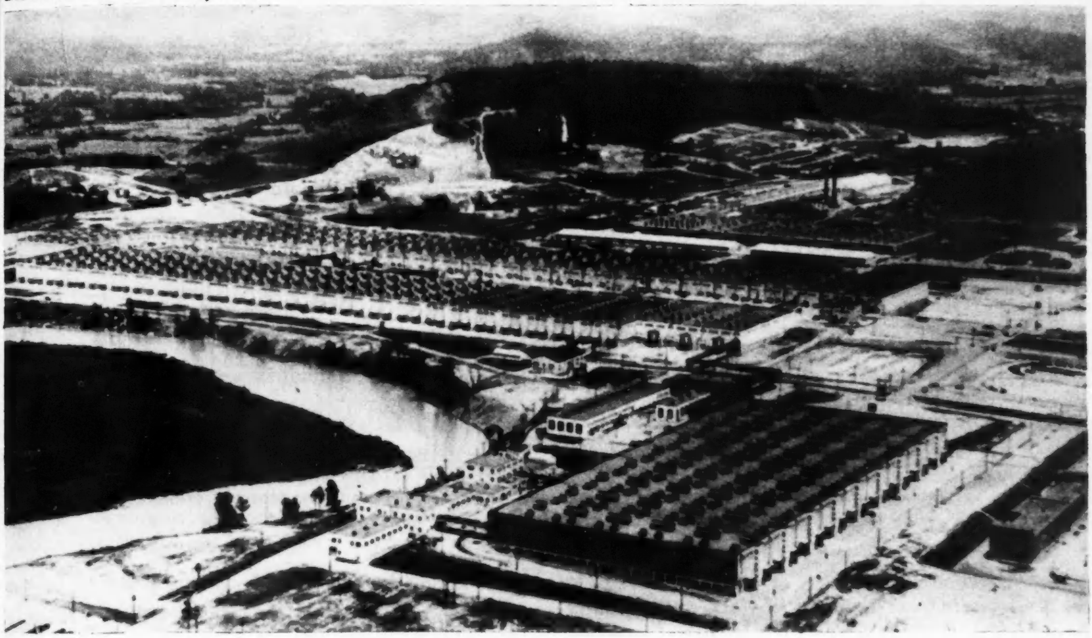


FIG. 3.—Large-scale production of fluorine had to be established before uranium fluoride could be made in quantities large enough to make the gaseous diffusion process for separating U235 practicable. This picture shows "K-25", the gaseous diffusion plant at Oak Ridge, Tennessee, which yielded U235 for the atomic bomb project.

individual molecules of each separate hydrocarbon determine its properties and appearance; thus, for example, the larger the molecules, the higher will be the temperature at which the hydrocarbon melts or boils, and because of the differences in their boiling-points the constituents of crude petroleum can be separated by fractional distillation. From the fractionation of petroleum there results a complete range of hydrocarbons, the first few members of which are inflammable gases, followed by low-boiling liquids, then by more viscid liquids with higher boiling-points, thick oils, and finally waxy solids (see Table I). The various hydrocarbons find use as motor fuels ('petrol'), lubricating oils, petroleum jelly, and paraffin-wax. When the hydrogen atoms in these hydrocarbons are substituted by fluorine, a comparable series of compounds consisting of *carbon and fluorine only*, the so-called 'fluorocarbons', are formed. To convert any hydrocarbon to the corresponding fluorocarbon, a mixture of the hydrocarbon-vapour and fluorine (diluted with inert nitrogen gas to moderate the interaction) is passed over a heated substance (e.g. copper turnings covered with a thin layer of silver fluoride), which acts as a catalyst and promotes a smooth and controllable reaction: the fluorine combines with and removes the hydrogen of the hydrocarbon molecules; the 'vacancies' are immediately filled by more fluorine atoms, so that all the hydrogen is rapidly replaced by fluorine, and the fluorocarbon is obtained. Other methods for the production of valuable fluorocarbons from petroleum products were also perfected; cobalt trifluoride, for example, that had become available as a result of the large-scale manufacture of fluorine, and hydrofluoric acid, proved highly successful 'fluorinating' agents for this purpose.

The fluorocarbons thus obtained are characterised by their great resistance to heat and chemical action. They are indifferent to the action of acids, alkalis and fluorine and, unlike hydrocarbons, do not burn. Since the individual fluorocarbons were found to have nearly the same boiling-points as the corresponding hydrocarbons, a similar range of gases, liquids, and solids became available, all of which had in addition the high stability characteristic of fully fluorinated substances. Although fluorocarbons are no longer required for the purpose for which they were first investigated and produced, namely for handling uranium hexafluoride, their properties suggest uses in many fields: their stability should make them excellent high-temperature lubricants, and fire-extinguishing substances. Some are plastics resistant to both heat and chemical action 'Fluon' (polytetrafluoro-ethylene, $(CF_2)_n$) is one such fluorine resin; it is available commercially as a fibrous white powder, which gradually changes to an amorphous rubber-like jelly when heated, and sets on cooling. It is fabricated into any desired shape by first pressing the powder in moulds and subsequently 'sintering' the article by heat. Although Fluon is still the most costly of all plastics sold in bulk, its unusual properties suggest it may come into use for special purposes: it is exceptionally stable; it is unaffected by concentrated sulphuric acid, nitric acid, or strong caustic soda; add to these features its insolubility in all solvents and its excellent electric and mechanical properties, and the reader will appreciate that it is a most remarkable plastic.

As previously indicated, not all the important work in fluorine chemistry was done after 1940. It was in 1937 in fact that T. Midgley received the Perkin Medal of the

TABLE I

Formula	*Name*	*Boiling pt. (degrees Centigrade)*			*Formula*	*Name*	*Boiling pt. (degrees Centigrade)*
CH_4	Methane	−164	*Gas*	*Gas*	CF_4	Perfluoromethane	−128
C_2H_6	Ethane	− 93	*Gas*	*Gas*	C_2F_6	Perfluoroethane	− 78
C_3H_8	Propane	− 45	*Gas*	*Gas*	C_3F_8	Perfluoropropane	− 38
C_4H_{10}	Butane	1	*Gas*	*Gas*	C_4F_{10}	Perfluorobutane	− 5
C_5H_{12}	Pentane	36	*Liquid*		—	—	—
C_6H_{14}	Hexane	69	*Liquid*		—	—	—
C_7H_{16}	Heptane	98	*Liquid*	*Liquid*	C_7F_{16}	Perfluoroheptane	82
$C_{14}H_{30}$	Tetradecane	—	*Liquid*		—	—	—
$C_{15}H_{32}$	Pentadecane	—	*Solid*		—	—	—
$C_{16}H_{34}$	Hexadecane	—	*Solid*	*Solid*	$C_{16}F_{34}$	Perfluorohexadecane	240
C_6H_6	Benzene	80	*Liquid*	*Liquid*	C_6F_6	Perfluorobenzene	82
C_7H_8	Toluene	110	*Liquid*	*Liquid*	C_7F_8	Perfluorotoluene	103

The Table compares hydrocarbons and fluorocarbons with the same number and arrangement of carbon atoms. Note the similarity of their boiling temperatures. Blank spaces have been left for fluorocarbons that have not yet been described in the pure state.

American section of the Society of Chemical Industry for the development, over a number of years, of the fluorine-containing refrigerating agents, called 'Freons'.* Although several good refrigerating agents, such as ammonia, sulphur dioxide, and methyl chloride, were known before Midgley's work, none combined the necessary properties required by the heat-engineer with complete non-inflammability and non-toxicity.

Although it seemed at first doubtful that a single refrigerating agent could be found that would satisfy all requirements, Midgley decided to examine fluorine-containing analogues of carbon tetrachloride (such as dichlorodifluoromethane, CCl_2F_2) and related compounds more closely. These substances were certainly non-inflammable, but it had not been established whether they were toxic or not. Midgley felt confident that these very stable fluorine compounds would be non-poisonous, and set out to settle this vital point. He bought five 1-oz. bottles of antimony trifluoride, probably the entire stock then available in the whole of America and used the first bottle to prepare a few grams of the gas dichlorofluoromethane ($CHCl_2F$): a guinea pig was placed under a bell jar containing this gas, and to the great surprise of the medical man present and to the chemists' delight, the animal did not die. In fact it did not seem to be affected by the gas at all. All Midgley's expectations appeared to have been realised. Anxious to check these results, he used the second bottle of antimony trifluoride to make some more dichlorofluoromethane. But this time the animal was quickly killed on exposure to the gas. On repeating the experiment with the third lot of antimony trifluoride, he smelled the gas before examining its effect on the guinea pig—and recognised the presence of phosgene. This poisonous gas had clearly come from an impurity in the commercial antimony trifluoride, and on examining the remaining two bottles he did in fact find impurities which would give rise to phosgene. By a lucky chance Midgley had taken the only pure sample for his first experiment, and so obtained pure dichlorofluoromethane. Had he used any of the other bottles of the trifluoride for that first test, the death of the animal would have been ascribed to the action of dichlorofluoromethane, and Midgley himself has said that further tests on dichlorofluoromethane would most probably have been abandoned because of its apparent toxicity.

Once their suitability for refrigeration purposes had been established, the production of several simple carbon compounds containing fluorine and chlorine, which became known commercially as 'Freons', was started. Dichlorodifluoromethane ('Freon-12') is a typical example: this is less toxic than carbon dioxide, and is non-inflammable so that it could be used in fire-extinguishers; its introduction marked a significant advance in refrigeration technology.

Other Fluorine Compounds

Now that the chemical industry has learnt how to handle fluorine the unusual properties of many fluorine compounds will increasingly attract the attention of the research chemist and engineer. Some of the simpler fluorine compounds have, of course, been commercially important for years. Hydrofluoric acid has long been used for etching glass, sodium fluoride and barium fluosilicate have found application as insecticides, and cryolite has been indispensable since 1911 in aluminium production. Other substances, like sulphur hexafluoride, were 'rediscovered'; this compound was described by Moissan, but the discovery of its remarkable properties for high-voltage insulation aroused renewed interest and this gas was prepared in large quantities once supplies of fluorine became available.

The availability of cylinders of compressed fluorine opened the way for experiments with a 'hydrogenfluorine-torch', which works on a similar principle to that of the well-known oxy-hydrogen and oxy-acetylene flames used for welding and cutting steel and other metals. Because of

* Refrigerating agents are low-boiling substances used in refrigerators, and cold storage and air-conditioning plant.

its great reactivity, fluorine burnt with hydrogen in the usual torch, gives a hotter flame than the other two flames mentioned (see diagram). The first trials showed that this intense bluish-white flame can weld copper and nickel with ease, and cut sheets of copper with a clean, uniform and almost knife-like action; with more experience, the 'fluoro-hydrogen' flame might become useful for special welding and cutting operations. Even more encouraging results are being obtained by employing fluorine trichloride instead of the element itself. It needs to be stressed that commercial use of such torches cannot become practicable until a great deal more development work has been done.

The most interesting aspects of fluorine chemistry, however, can be expected to come from the organic synthetic laboratory. Fluorine, being a member of the 'halogen-family' of elements, is most closely related to the elements chlorine, bromine, and iodine, which figure prominently as the constituents of an enormous number of organic compounds, many of which possess physiological activity. It will be very rewarding to synthesise the corresponding fluorine-containing substances and study any variations in properties caused by the introduction of fluorine in place of its less violent cousin, chlorine. Results along these lines have already been reported, both in this country, particularly from the University of Birmingham, and in the United States. Thus, for example, replacement of chlorine by fluorine in the comparatively harmless chloracetic acid yields the very toxic fluoracetic acid; compounds of the 'fluoroacetate'-series (containing the $-CH_2F$ group) cause, after a delayed action, violent convulsions and death; their use as rat-poisons has been suggested. Analogues of the well-known insecticide DDT (dichlorodiphenyl trichloroethane), which contain fluorine in place of the usual chlorine atoms, have been reported to give even better service than DDT itself. 'DFDT' (difluorodiphenyl trichloroethane), for example, has been noted for its greater speed of action, its low toxicity to warm-blooded animals, and its greater volatility, which reduces the danger of undue accumulation of this substance after several applications.

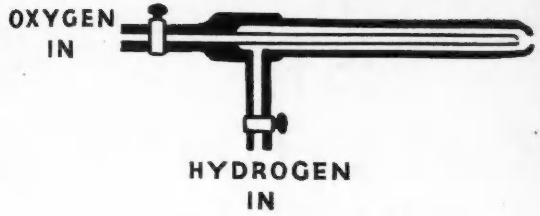


FIG. 4.—The oxy-hydrogen torch; oxygen is fed into the heart of a hydrogen flame and a very high temperature results. An even hotter flame is produced when fluorine is substituted for oxygen. Fluorine trichloride can be used instead of fluorine.

In this brief account of fluorine chemistry, we have had no more than a glimpse of the unique properties of this 'extremist' amongst the elements, which affords, on the one hand, compounds of great stability and inertness, and, on the other, violently reactive substances. We have also seen that while many fluorine derivatives are among the most non-toxic materials known, others are highly poisonous and kill swiftly in small concentrations. The extension of our knowledge of chemistry gained by our increasing experience of extreme properties exhibited by fluorine will not stop at merely adding new and unusual materials to the technologists' armoury; the increasing body of new data allows scientists to test and extend our theories of chemical structure and combination, and to make predictions about the behaviour of compounds yet to be discovered.

The story shows how pure academic research, pursued in the face of disappointment and danger and without thought of immediate reward, by small bands of pioneers, has laid the foundation for great developments. Moissan and his earlier followers, as well as their numerous modern disciples, could have no more fitting monument to their efforts than our ever-increasing knowledge of the chemistry of fluorine.

NIGHT SKY IN FEBRUARY

The Moon.—Full moon occurs on Feb. 2d 22h 16m, U.T., and new moon on Feb. 16d 22h 53m. The following conjunctions with the moon take place:

February			
5d 10h	Saturn in conjunction with the moon	Saturn	0.4° N.
7d 02h	Mars ,,	Mars	4° N.
14d 18h	Mercury ,,	Mercury	5° N.
14d 22h	Venus ,,	Venus	13° N.

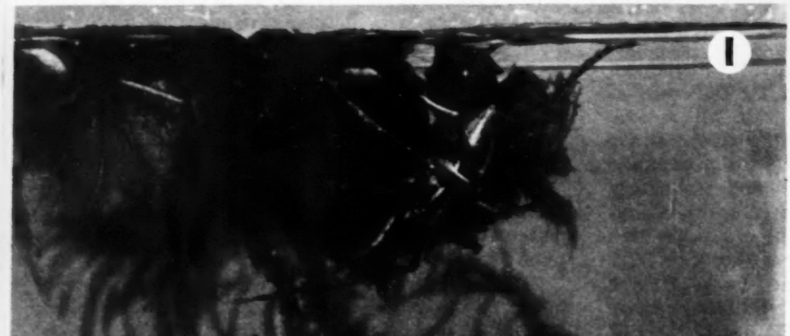
In addition to these conjunctions with the moon, Mercury is in conjunction with Venus on Feb. 16d 05h, Mercury being 8°.4 S.

The Planets.—Mercury is a morning star, rising nearly 1¼ hours before the sun on Feb. 1 and less than ½ hour before the sun on Feb. 28, but is not an easy object to observe during the twilight. At the beginning of the month Venus is too close to the sun for observation as the planet attained inferior conjunction on Jan. 31, but at the middle and end of February it is visible as a morning star, rising more than 1½ hours before the sun. Mars rises at 22h 06m, 21h 18m and 20h 18m, at the beginning, middle and end of the month, respectively. Notice that it is a little east of the star Gamma Virginis and moves farther east from it until Feb. 14, when it is stationary and then moves westward so that it is very close to Gamma Virginis at the end of the month. Jupiter is in conjunction with the sun on Feb. 3, that is, the earth, the sun and Jupiter are nearly in a line so that Jupiter rises and sets about the same time as the sun. Later in the month Jupiter becomes a morning star but rises too soon before sunrise to be observed. Saturn is visible throughout the night, rising at 20h 10m and 18h 10m at the beginning and end of the month, respectively, and can be seen in the constellation of Leo east of Sigma Leonis to which it draws nearer, so that at the end of February the planet and the star appear very close. It is useless looking out for Saturn's rings now or, indeed, for some time because their plane passes very near the earth.

Look out for an interesting phenomenon on Feb. 5d 22h 25.9m. The star Beta Virginis (not very bright especially in the strong moonlight, but use a pair of binoculars) is occulted by the moon, that is, the star passes behind the moon, or to be more correct, the moon moves in front of the star, some time before the hour mentioned and so the star is invisible, but just before 10.26 p.m. the moon in its easterly motion round the earth uncovers the star. Look at the right hand side of the moon, and, reckoning about 4 o'clock if you regard the moon's face as a clock, you will see a star that was previously invisible. It will slowly recede from the moon and in an hour will appear about the diameter of the moon away from her limb.

M. DAVIDSON, D.Sc., F.R.A.S.

A FISH-CATCHING SPIDER



FISH-CATCHING SPIDERS have been from several
cluding North and South America, nd New Zeala
species, *Thalassius*, of which there ral varieties,
Greytown, about forty-five miles rmaritzburg,
1911, when it was observed fishing e aquarium.
Thalassius frequents the banks and pools.
speedily on the water surface, being d by surface t
When fishing the spider usually ld of a floatin
with the rear legs, whilst the remai st in the wate
of small fish, tadpoles or frogs is pparently by
when the spider plunges beneath . The attack
pattern—all legs are wrapped tight the victim, w
deep into the backbone just behind The victim s
a minute or so the venom takes effe battle is ove
spider's hairs produces sufficient bring it and
The spider drags the carcase on to on to floatin
suck the fish's blood at leisure. s not during
struggle the spider changes its grip, e fangs are u
victim's eye-sockets.
A single spider has been observed everal fish, all
course of a few hours. Fish-breede lly aware of t
which they regard as a serious pest.
Spiders kept in aquaria have been attach a thr
devoured fish before lowering it ag e water where
below the spider's resting place. Only is it observed
up again, and feeding resumed after l of some hou
whether the habit is dictated by a des ain possession
the suspended carcase is used as a b act further vi
silk may even be purely accidental.
The first photograph shows the king among
prey approaches it plunges downwa les the victim
its fangs into the fish's back. 2. *Th* run with eas
3. Poison from the spider's fang pa prey, which
where the spider feeds on the carcase ish in the pic
The diving spider carries with it a which enables

os by Roderick

ERS have been from several parts of the world, in-
South America, nd New Zealand. The South African
of which there ral varieties, was first reported from
ty-five miles fr rmaritzburg, the capital of Natal, in
served fishing te aquarium.
ts the banks of and pools. It is capable of running
surface, being d by surface tension.
spider usually ld of a floating leaf or similar support
hilst the remain st in the water surface. The approach
es or frogs is apparently by transmitted vibrations,
ges beneath th . The attack always follows the same
wrapped tight the victim, whilst the fangs are sunk
he just behind The victim struggles violently, but in
nom takes effe e battle is over. Air entrapped in the
es sufficient bu bring it and its victim to the surface.
carcase on to th on to floating leaves, and proceeds to
at leisure. A s not during the later stages of the
hanges its grip, e fangs are usually re-inserted in the

been observed veral fish, all larger than itself, in the
s. Fish-breede ly aware of the habits of this spider,
a serious pest.
uaria have been attach a thread of silk to a partly
lowering it agai e water where it hangs an inch or two
ting place. Onl s it observed that the meal was pulled
resumed after l of some hours. It is thus not known
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e is used as a b act further victims; the attachment of
ely accidental.
ph shows the king among floating weeds; when its
unges downwa les the victim with its legs and strikes
s back. 2. *Thal* run with ease on the surface of water.
ider's fang para prey, which is brought to the surface
ls on the carcas sh in the picture is 2 inches long.) 4.
ries with it a fil which enables it to breath under water.
os by Roderick A. Holliday, F.R.P.S.)

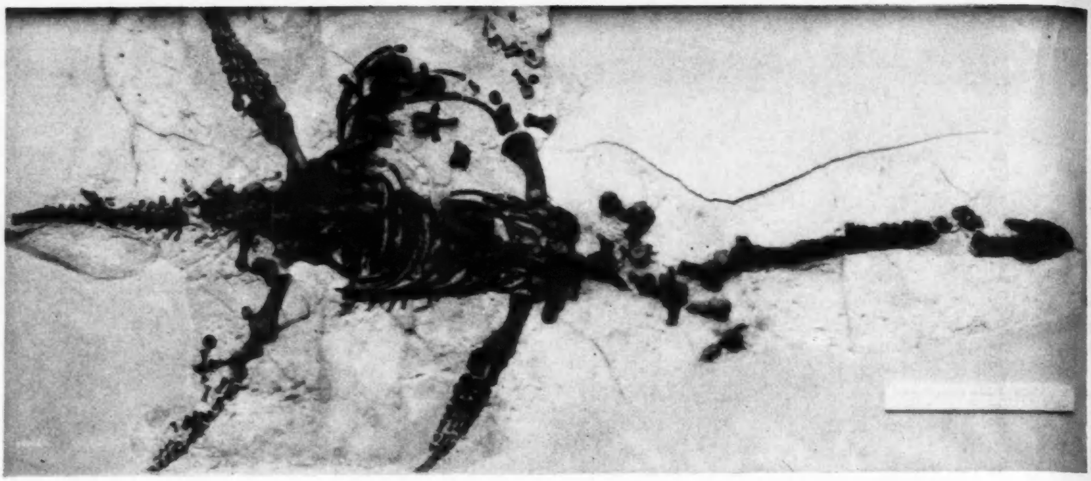


FIG. 1.—*Plesiosaurus dolichodeirus.* The first skeleton of a plesiosaur to be discovered. Found at Lyme Regis by Mary Anning in 1821. Now in the Natural History Museum at South Kensington.

FIG. 2.—*Hypsilophodon foxi*, a tree-climbing dinosaur. The picture shows an adult and a young specimen, the adult being about 5 ft. from snout to tail. *Hypsilophodon* was first described from the Wealden of the Isle of Wight by Thos. Huxley. It is a relative of *Iguanodon*. Model by Vernon Edwards. (*Crown copyright reserved.*)

British Prehistoric Reptiles

W. E. SWINTON, Ph.D., F.R.S.E.

OLIVER GOLDSMITH spoke of the writer 'who excelled at the title page'. I cannot claim to be such a writer, for I disapprove of the term 'Prehistoric Reptiles'. I presume it is tolerated, even widely used, because it implies that these animals lived before the days of written history. None the less, their history is wholly derived from the rocks where their own remains of bone, skin impression, and footprints constitute a record as clear as if they had been recorded in a carved stone with hieroglyphics.

Their records are of the rocks, for it is only as fossils that we know these reptiles, who had played their part and withdrawn from primeval history before the advent of even the most primitive man. Despite their early disappearance from the scene of Life's history their part was not inconsiderable. It was a great chapter in the history of life—perhaps junction would be a truer simile, for the reptiles were derived from the early tetrapods who had just managed to struggle towards mastery of the land—but a junction whose single line with the past branched into three forwardly directed tracks represented by the reptiles of the present, the birds, and the mammals.

These new lines of development were not brought about in a day or a million days. The earliest reptiles of this country are of Permian age, which is computed to be about 215 million years ago. The time of the great reptiles ended about 65 million years ago. Thus, for 150 million years, approximately one-tenth of the whole history of life itself, reptiles in one form or another, in one element or another, were undisputed monarchs of their 'prehistoric' world.

They are often called monsters—but many were small and probably gentle; they are sometimes called terrifying, but the largest of them all were herbivorous, as are, indeed, the largest of today's land animals: they are seldom called attractive, yet some must have been quite delightful in their coloured but scaly coats as they climbed the branches of the dark green vegetation of their time.

Throughout the fantastically long period of their reign the reptiles were world-wide in distribution. It may seem, therefore, that to write of British forms is an excess of insularity and history in short measure. Strangely enough it is not so. We are used to hearing of British inventions, often and vigorously developed elsewhere; our knowledge of fossil reptiles is largely due to British discoveries made by British scientists in the southern half of this country. The first forms of many great groups of reptiles were found and named in England, so that it may be a salutary reminder to modern generations to record the facts, and to lay a modest tribute to the memory of these pioneers who worked so diligently and so well and who now, like their trophies, have passed from the living scene.

The world in which the early reptiles lived was very different in appearance from that we see today. Geographically it was markedly so; climatically it was warmer, at least in the northern hemisphere, than it is now, and the plant background was quite different from our familiar world of deciduous trees and flowering shrubs. For most of the time there were no true flowers; no leaves to make the 'fall'. Instead, there was often an abundance of darkish green conifers, of giant fern-like growths, of horsetails and other large ancestors of small forms of today.

The reptiles were finding their feet literally on the dry land and had left the amphibiousness of their ancestry behind. Already they were spreading out, conquering in easy stages the world that was new to four-footed masters. The earliest forms, the reptilian Adams, were large, sprawling creatures, about 8–10 feet long. They walked with their bellies upon the ground and with their arms and legs stuck out from the body, with the elbows and knees bent at right angles.

These animals are characterised by the bony and continuous coverings of their heads. They had openings for the eyes and nostrils in this shield. They are known as cotylosaurs, though they are often called 'stem reptiles', because in a way they were the stem from which many different kinds of reptiles were derived, some few of which are with us today. The cotylosaurs are found in many parts of the world but especially in South Africa. None the less, one form is known from Britain—*Elginia*, from Elgin in Scotland, a remarkable little animal with a skull highly ornamented with spikes.

From the stem reptiles many others were derived, most of them strangely different in appearance and habit from the few kinds of reptiles we see living today.

Most of them became highly adapted to life on the land. Yet some of them became tired of the restrictions of land life apparently, and returned to the ancestral living-place—the water. We know a good deal about these secondarily aquatic forms, and they are well represented in this country. A curious personal coincidence can be related about some of these forms.

At Lyme Regis, in Dorset, in the early days of the last century there was a little girl who had become interested in the fossils which were frequently discovered in the stone quarries of the district or on the beaches.

She was of humble origin, her father being a carpenter, yet her name is revered by palaeontologists to this day, and not long ago the Geological Society of London erected a stained glass window to her memory in Lyme Regis parish church. Her name was Mary Anning.

In 1811, when she was only twelve years of age, she discovered the first ichthyosaur. These are large swimming reptiles of fish-like shape except that they had the four limbs modified for use as paddles. They had a small triangular fin on the back and a large tail fin, superficially like that of a fish. In size they might be anything from a few feet to thirty feet. The powerful tail was used to propel them through the water, the limbs being used as paddles to keep the animal on an even keel and to help in turning. The body was large, the neck very short, and the head was long and nearly all taken up by a thin wedge-like beak. The jaws were lined by sharp teeth so that the mouth was a veritable fish-trap, for fish were their prey.

Nearly 100 years ago an English doctor was examining the stomach contents of ichthyosaurs when he discovered the remains of little ichthyosaurs. After a great deal of study—and argument—it has been proved that the ichthyosaurs

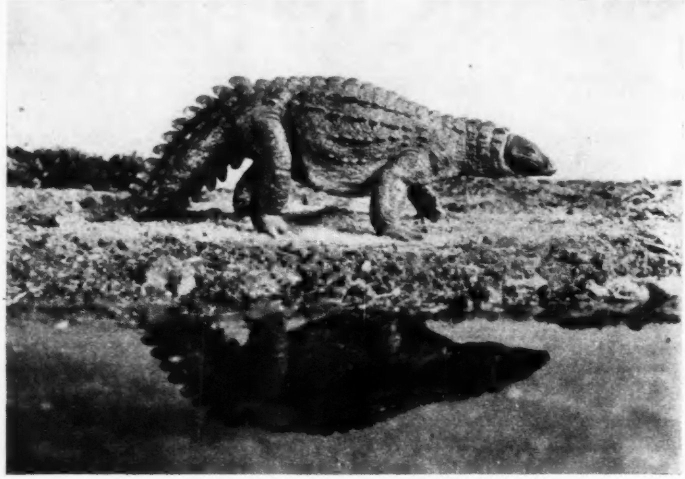


FIG. 3.—*Scelidosaurus harrisoni*, an armoured dinosaur from Dorset. Photographs from a modelled landscape by Vernon Edwards. (*From W. E. Swinton's book, "The Dinosaurs."*)

did not lay eggs, like most reptiles, but that the young were hatched out in the body. The little ichthyosaurs were thus the remains of unborn young. The implications of this is that these reptiles were free from the last link with the shore, the need to lay eggs on dry land, so they could and did roam the surface of the high seas in search of their prey.

In this they were more fortunate than a group of their relations, the plesiosaurs. Their name means 'nearer a lizard' and they were in appearance much more lizard-like. Of much the same size as ichthyosaurs, they had a barrel-shaped body, a well-marked, often long, neck and a tail without a large fin. Indeed there were no fins on this body, and propulsion was done by the oar-like limbs. These limbs were true paddles that pushed or turned the animal and could also 'back water'. The skull, small in some forms, large and like that of a crocodile in others, had sharp teeth like those of the ichthyosaurs, suited for the same purpose. We know that plesiosaurs ate fish and cuttlefish, and to help to grind up the hard parts they swallowed pebbles—known as gastroliths or stomach stones. We can still examine masses of these stones, within the ribs of the reptiles, mixed with fish remains and the hooks of the cuttlefish. Plesiosaurs were less free in action, and were paddlers of the shallower seas, the females returning to the shore to lay their eggs.

The first plesiosaur was discovered at Lyme Regis, by Mary Anning, in 1821.

The lands and the seas were not enough for the conquering reptiles of the past. They tried, and succeeded, in the air. These flying reptiles are well known as the pterodactyls. Their name ('wing finger') gives the clue to their habits. The pterodactyls were of several kinds and many sizes.

Some were no larger than a sparrow, others rivalled the albatross. All of them had smallish bodies, weak hind legs that could barely support the weight, but strong arms and enormously lengthened 'little' fingers. This long finger-bone and the upper arm supported a web of skin that was also attached to the body and the thigh. With arms outstretched they glided over the land and the seas; some catching insects, others diving like birds to snatch a fish from the waters. On land they roosted, hanging upside down from the trees or rested with wings folded back. Some of the pterodactyls had tails that were stretched out behind in flight; some were tailless. Most of them had thin sharp teeth in their jaws, but some of the largest and latest had no teeth at all. All of them had hollow bones, like those of birds, for lightness. Although they were probably egg-laying reptiles, it seems likely that some of them developed the unreptilian character of warm blood.

Warm-bloodedness would help their metabolism to meet the needs of increased energy associated with flight, even largely gliding flight, but it is dependent upon a body covering suitable for the retention of heat. It is significant, therefore, that a very finely preserved pterodactyl in Munich shows the remains of hair.

The first pterodactyl to be found in this country came from Lyme Regis and was found, as you may have guessed, by Miss Mary Anning, as the last of her major triumphs in 1828.

So much for the reptiles of the seas and of the air. What was happening to those who stayed on the land? We find that they flourished too in a number of ways but especially in the development of an interesting series of reptiles that were often of very great size.

Between the times that Mary Anning found the first plesiosaur and her first pterodactyl, another assiduous collector was working in another part of southern England. He was Gideon Algernon Mantell (1790–1852), a medical practitioner of Lewes in Sussex and subsequently of London.

He was a man of extraordinary energy, who, despite the calls of a busy professional life, found time to make extensive natural history collections and palaeontological studies. While at Lewes he and his wife collected from the Wealden rocks near Cuckfield (in Tilgate Forest). He collected between 1822 and 1825 a number of interesting bones and teeth of an unknown animal. Owing to the similarity between these teeth and those, though much smaller, of the living *Iguana* the new fossil animal was named *Iguanodon*. It was the first reptile of its kind ever to be discovered, though not the first of this kind to be scientifically described.

When it became more thoroughly investigated it was clear that the living *Iguanodon* must have been a large bipedal animal. It had strong hind legs, with three-toed feet rather like those of a large bird. Its body was large and was maintained in the bipedal position largely through the counter-balance of a long muscular tail. The fore limbs were less strong than the hind limbs, and the hand had five fingers. In this hand the thumb was a large bony spike used, no doubt, to help to dig vegetation off the trees, and also at times in fighting. In some of the early attempts to reconstruct the living appearance of this animal the thumb spike was mistakenly placed upon the nose. The head, like the feet, had some qualities reminiscent of the birds. The mouth, for example, had teeth suited for chewing vegetation along the sides of the jaws, but a hard bony and toothless beak was developed at the front. Pieces of vegetation were

nipped off by the beak and reduced to digestible matter by the chewing teeth.

Iguanodon is known by about ten different species, some smallish and others large. The first species was named in 1829, and the last in 1924, and it is interesting that much of the material, including that of these particular species, was discovered by amateur workers. A fair-sized specimen measures about 14 ft. high and 30 ft. along the backbone.

We now know a very great deal about *Iguanodon*, even of the nature of its skin, and it conveys something of the kind of life characteristic of 100 million years ago in this country.

In 1841 Professor Richard Owen, searching for a comprehensive term to apply to such animals, coined the word 'Dinosauria' (Greek for 'huge lizards'). In its shorter form, Dinosaur, this has become a household word throughout the world. It is not, however, a very accurate one, for it is now well known that not all of this group of reptiles were by any means huge and they do not all belong to one group in any case.

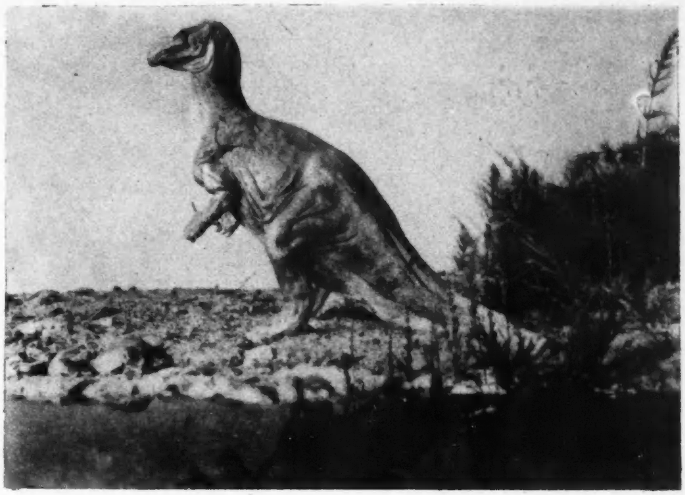


FIG. 4.—*Iguanodon.* How it probably appeared in life. Model by Vernon Edwards. (*From the author's "The Dinosaurs."*)

Iguanodon is a typical bipedal member of one group which had quadrupedal, plant-eating, cousins that were all armoured against predacious contemporaries. Such a four-footed form was *Scelidosaurus*, from the Lower Lias of Lyme Regis, collected by James Harrison, a retired physician, and named by Owen. This dinosaur had rows of keeled bony plates along its body and a series of low spines on the tail. In some ways it closely resembled a terrestrial crocodile, and indeed the crocodiles are the nearest living relatives of the dinosaurs.

Others of the English armoured dinosaurs (such as *Stegosaurus*) had upstanding plates or spines arranged along the back as deterrents to their enemies.

These enemies were superficially like *Iguanodon*, bipedal forms of approximately the same size. They had, however, no toothless beak, but were well supplied with sharp, sometimes serrated, teeth. There are, of course, other differences in the skeleton, especially in the nature of the pelvis.

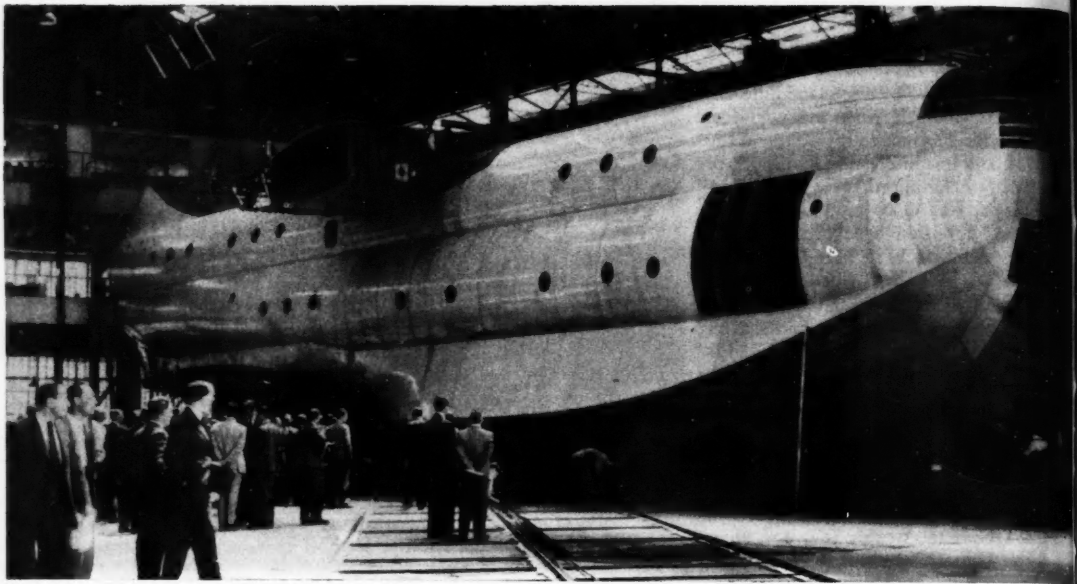
We know a large number of bones of English predacious dinosaurs, but our knowledge of the whole animal is not so clear as that of the *Iguanodon*. The most typical English form is *Megalosaurus*, named by Professor Buckland in 1824 upon some jaw fragments from Woodstock. Since that time a nearly complete but smallish example was found in Oxfordshire and is now mounted in the University Museum, Oxford. *Megalosaurus*, despite its name, was neither so impressive nor so highly specialised as some of the American flesh-eaters, which were truly terrifying of tooth and claw. *Tyrannosaurus*, the largest known flesh-eating dinosaur, was almost fifty feet from snout to tail.

The plant-eating bipedal dinosaurs had armoured quadrupedal relations; the flesh-eating bipeds had four-footed relatives too, but they had no bony armour. Instead, they sought protection from their enemies in bulk, and in the safety of inland waters—and were the largest land animals of all time.

The typical English example, *Cetiosaurus*, was a mere 60 ft. in total length, but some American forms were nearly 90 ft. long (*Diplodocus*). These creatures had small heads, very long necks, elephantine bodies and very long tails. The jaws were feeble and the teeth few and rake-like, their purpose being to harvest succulent vegetation or water weed. The long neck would enable the animal to do this in comfort and safety even in the deepest waters. Living in the waters of lakes and river pools, the enormous weight of the animals, in some cases nearly 20 tons, could be mitigated, yet the comparatively strong and heavy limbs, and the claws on the feet, would serve to anchor the creature and keep it on an even keel. The method of locomotion of these animals has been the subject of much controversy. They were undoubtedly suited for the kind of life outlined above, but equally clearly the females must have emerged and waddled over dry land to lay their eggs. Whole herds of them, males as well as females, must have wandered from pool to pool in times of drought or when favourite pools were drained.

It is easy to see that the lives of such monsters hung on slender threads of geological and geographical change. It is not surprising that the race died out. Yet it is not so easy to see why all the other dinosaurs should have died out too; and when one adds the ichthyosaurs, plesiosaurs and pterodactyls as well, it becomes an insoluble problem. It is difficult to see what set of external circumstances could have exterminated all these reptiles of every element at approximately the same stage of history—about 65 million years ago.

The reptilian survivors—crocodiles, turtles, tortoises, and snakes—are the few and unimpressive remnants of a great lineage, but the passing of the great forms released, as it were, a new wave of development, that of the mammals, and this, though it rivals neither in length of time nor in spectacular forms that of its predecessor, has produced the most highly developed creatures we know and Man, in whose charge is now the destiny of all.



Three 'Princess' class flying boats are under construction at Cowes. This photograph was taken in the summer of 1949, when the completed hull of the first of the three machines was moved to the centre of the Saunders-Roe works for the wing assembly to be attached.

The hydrodynamics of a flying boat must be considered as well as its aerodynamics. Here a model of a 'Princess' is being tested in a water tank.

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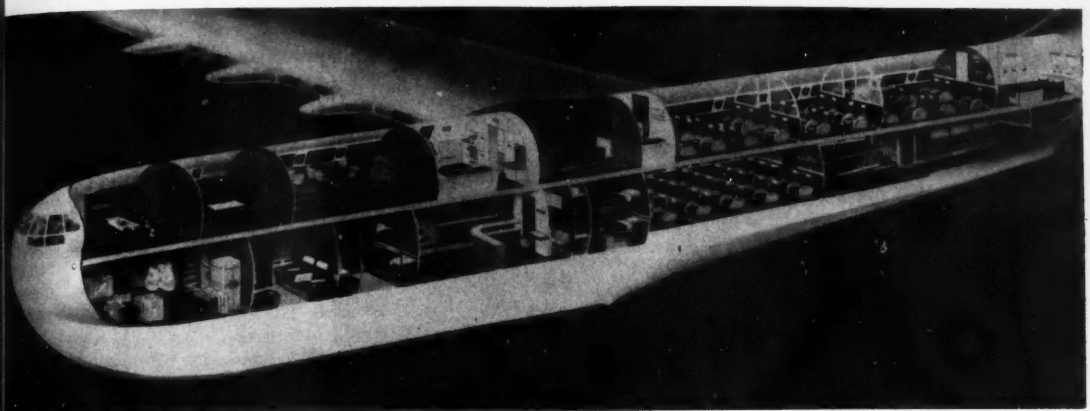


Interior design for Princess Flying Boat.

The Future of Flying Boats

THE big four-engined flying craft that speed down Southampton Water, rising swiftly above the ocean ships and setting course for some distant part of the world, strike a maritime nation like ourselves as being a natural development in overseas travel, merging as they do the modern air age with our centuries-old sea tradition. This merger will take a big step forward in 1953 when the three giant 'Princess' class flying boats, now being built at Cowes, Isle of Wight, go into service on British Overseas Airways routes.

Ten tons heavier than the great Brabazon (though not quite so large in wing span and length), the 'Princesses' will bring this line of evolution right into the jet-propulsion era.

Each of the three luxurious flying ships (at 140 tons all-up weight they surely must be removed from the 'boat' category) is to be driven by ten propeller-turbines, giving a total of 35,000 horse-power enabling it to cut through the skies at 400 m.p.h.

In the Saunders-Roe works alongside the water's edge, the three great air ships are taking shape. The hull of the first has already been taken from the stocks—yes, they are built almost in shipyard fashion. In the summer of 1951, this huge aircraft will ride down the slipway into the waters of the Solent ready for chief test pilot Geoffrey Tyson to carry out the initial flight trials.

While construction work goes on at Cowes on the 'Princesses'—'Dollar Princesses' as they have been dubbed rather hopefully—experts of British Overseas Airways are planning smaller jet-propelled flying boats with a view to operating sea-based aircraft on the transatlantic route once again.

Quite recently, Sir Miles Thomas, the corporation's chairman, called on his experts to draw up a report for him on the possibilities of operating fast, 60-seater jet-engined flying boats on the Atlantic route.

The 'Princesses' were originally ordered for British South American Airways, now merged into B.O.A.C., and it is not yet certain where they will be used. But whether they fly over the South Atlantic or the North Atlantic—they will have sufficient range to fly non-stop from Southampton to New York—they will be the last word in luxury.

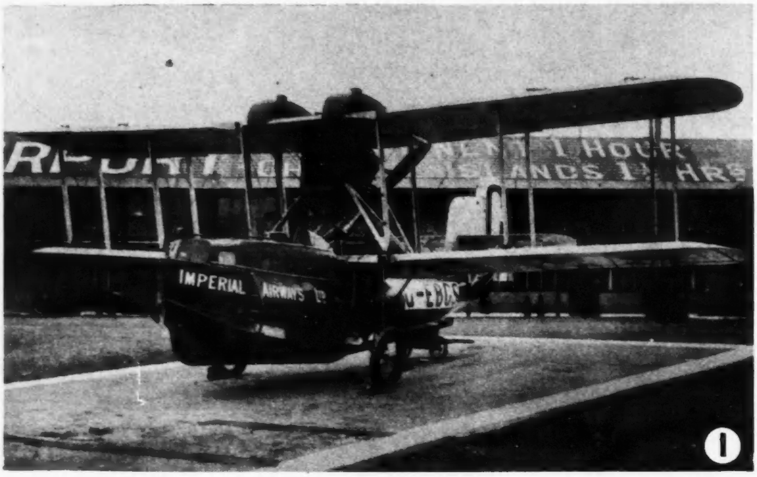
In their two decks, they will be able to carry up to 105 people. There will be spacious dining saloons and lounges, cocktail bars and, if necessary, sleeping accommodation. The hull is the largest metal structure ever built to fly, using 1469 square yards of plating, held together by over three million rivets. Everything possible has been done in designing the great 'Princesses' to eliminate 'drag' so that the enormous power of the ten Bristol 'Proteus' propeller-driving gas-turbines shall not be reduced in overcoming unnecessary air resistance. The 140 tonners will be remarkably 'clean' aerodynamically. In hydrodynamics, too, the 'Princesses' will set new standards. On the Isle of Wight, Saunders-Roe's have the largest water tank in the country for testing hull and wing float forms, and they claim that the enormous size of the 'Princess's' hull, its strength, and its hydrodynamic qualities will ensure a seaworthiness not yet approached in a flying boat. Further tests have been carried out, too, at the Royal Aircraft Establishment, Farnborough, and these have confirmed both the aerodynamic and hydrodynamic efficiency of the huge flying ship.

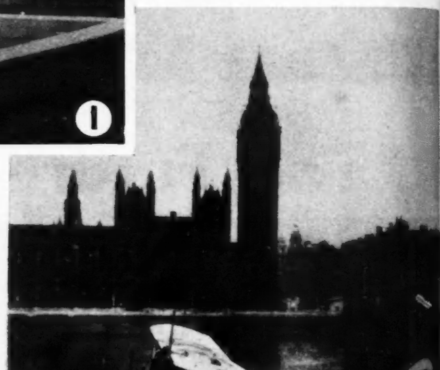
As in the Brabazon, the new form of engine-coupling is being employed. The ten 'Proteus' engines, each rated at 3500 h.p., are to be fitted in four pairs and two single units. The 'singles' are to be in the outboard positions. So the 'Princesses' will give the appearance of a six-motored aircraft. The engines will drive propellers 16½ ft. across—eight-bladed on the 'double' engines; four on the singles.

Not only is the hull built to withstand great pressure from the water when taking off or 'landing', but it is built so as to operate at great altitudes which means, of course, pressurising the fuselage. It is built to withstand an internal pressure of 8 lb. per sq. in., which, over the whole vast area amounts to a pressure of 2900 tons.

This will give the passengers the air conditions normally met at 8000 ft. when flying at the 'Princess's' maximum operating height of 40,000 ft.

THE EVOLUTION OF THE FLYING BOAT





1. The Sea Eagle, an outstanding pioneer of civil flying boats.

2. Imperial Airways all-metal flying boat 'Calcutta' on the Thames.

3. The 'Caledonia', one of the 'C' class flying boats and the first seaplane to fly the Atlantic.

4. B.O.A.C. Solent flying boat 'City of York'.

All the photographs on this page are from B.O.A.C.

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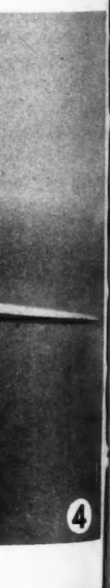

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A great deal of research and development work has gone into this pressurisation. A full-scale section, built into vast concrete end walls has already been tried out. In the tests, it has been 'pumped up' to twice the pressure required, being overloaded to 16 lb. per sq. in., and has passed all the requirements of the Air Registration Board.

Again like the Brabazon—it is necessary in all aircraft of such size—the controls are to be power-operated.

Dimensions of the 'Princess' are: wing span 219 ft. 6 in.; length 148 ft.; height 55 ft. 9 in.; beam 16 ft. 8 in. Still air range is 5500 miles; cruising speed 380 m.p.h.

The design team under chief designer Mr. Henry Knowler, A.M.I.C.E., F.R.Ae.S., have planned the greatest all-up-weight flying boat ever to be put into service. (The American wooden-constructed Howard Hughes flying boat is bigger than the 'Princess', but has lain idle for two years.) It is likely that the 'Princess' will remain for some time the maximum size for transport aircraft, but if bigger flying boats are wanted, Mr. Knowler's design team will be able to call on their experience of producing the 'Princess'.

Before the war, flying boats had practically 'their own way' on our long distance air routes. But since the war there has been a lot of discussion as to the merits of the flying boat as compared with the landplane. We have seen landplanes supersede the pioneering flying boats on the transatlantic route; wheeled aircraft introduced on the Empire routes where once the flying boat was supreme.

At one time it looked rather as if the flying boat, preserved largely by Britain, was going to disappear. But the sea-based aeroplanes are still flying every day on the 'Springbok' route to Johannesburg. This is practically an overland route and is operated in conjunction with the landplanes of South African Airways. The landplanes do the journey more quickly than the Short Solent flying boats, but the flying boat service is immensely popular. How is it that flying boats operate to Johannesburg, miles from the sea? They alight on the Vaaldam, a big artificial lake just outside the city made by damming the River Vaal.

B.O.A.C., however, recently announced that the Solents would be withdrawn from the South Africa route next summer when the new Handley Page 'Hermes' landplanes were ready for service. This will mean that for the time being, at any rate, Britain's official airlines will have no flying boat services and that B.O.A.C.'s flying base at Hythe, Southampton Water, will be shut down.

But a private charter company will continue its operations with 'Hythe' class flying boats. Whatever new landplanes may come along and whatever developments may come along in high speed jet flying (and the recent flight of the de Havilland 'Comet' from London to Castel Benito and back in 6½ hours shows how we lead the world in landplane transport) many experts think that Britain will always operate some flying boats.

There is one school of thought in the air transport industry which is in favour of future services being operated by medium-sized aeroplanes, being utilised at high frequency. Others vote for large aircraft of the 'Brabazon' and 'Princess' type. There will probably be room for both, but when one comes to consider large aircraft there are operational factors which make the development of huge flying boats a more practical proposition than that of huge wheeled aeroplanes.

Although landplanes are operating highly successfully over the Atlantic just now, I should not be sorry to see B.O.A.C., when they are in a position to use British-built aircraft on that route, re-introduce the flying boat—such as the 60-seater visualised by Sir Miles Thomas. Whenever the flying boat *versus* landplane subject comes up for discussion so far as long over-water routes are concerned, the flying boat enthusiasts quote the example of the American charter flying boat which was forced down in the Atlantic a couple of years ago and rode out the Atlantic waves long enough for those aboard to be taken off by a weather patrol ship.

Such mishaps are fortunately rare, but there is a lot in having an aircraft designed for water use when it is forced down on to the sea probably 1000 miles from the nearest land!

So far as the really big machines go, flying boats are probably more easily operated. Admittedly there are plenty of airfields where aircraft the size of the Brabazon can land. But are there enough? As the weight of wheeled aircraft goes up, the depth (and therefore the cost) of the runways they use, must increase proportionately. Runway strength is the limiting factor; I do not think that length comes into it having seen the Brabazon take off and land. So if aeroplanes of the 150–200 ton class are built in the future, special runways will have to be laid down. Then the question of emergency diversions is raised. If, say, in Britain there were only two airports where a 200-ton landplane could land, what is to happen if for some unforeseeable reason both should be 'closed'? But with the flying boat, all that is needed is a suitable stretch of water. In the long run, too, airport maintenance costs are heavily reduced.

Critics of the flying boat have always accused it of being so much slower than the more streamlined wheeled aeroplane, but Sir Arthur Gouge, head of Saunders-Roe, and other flying boat men say that there is no reason why, with powerful jet engines, the flying boat should not be made as fast as the landplane. So perhaps we can visualise that in future we shall travel about the world in 500 m.p.h. flying boats propelled by 'pure' gas turbines, leaving out the propellers of the 'Princesses' and relying solely on the thrust of the jets.

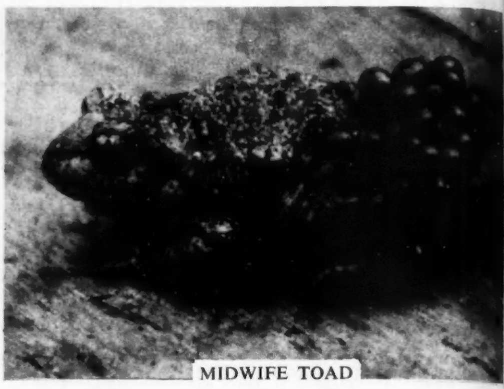
At any rate, the 'Princesses' themselves should take us quite a way into the future. If they do not begin operations until 1953, they should at least be flying still in the early 1960's.

We have seen the flying boat progress a long way from the three-engined 'Calcuttas' introduced just twenty-one years ago, which cruised at 90 m.p.h., or the 'Kents' that followed them. Both were fabric-winged bi-planes. The 'Kents' with a fourth engine had a five miles per hour speed advantage over the 'Calcuttas'. But the total horse-power of the 'Kent's' four Bristol 'Jupiters' amounted only to roughly two-thirds of the power output of one of the engines that are to be fitted to the 'Princesses'.

It was the famous Empire flying boat—also known as the 'C' class—which really established the flying boat traditions on Britain's world skyways. These grand old 'ships', 'Canopus', 'Caledonia', 'Cabot', 'Caribou' and the rest—all had names beginning with 'C'—did an enormous amount of pioneer work. 'Canopus' was the first of this line, and she and her sister ships were continuously making

Continued on p. 62

RED-LEGGED PARTRIDGE



MIDWIFE TOAD

Man's Additions to the British Fauna

R. S. R. FITTER

Of some sixty-three species of terrestrial mammals living wild in the British Isles at the present date, as many as thirteen have been introduced either deliberately or accidentally by man over the past two thousand years, more than half of them within the past hundred years. The proportion of birds is somewhat smaller, about half a dozen out of a little more than two hundred breeding species, but with both reptiles and amphibians it is four out of ten. Ten of the mammals, three of the amphibians and the four reptiles have been introduced so recently that they are not mentioned in the list of British vertebrates published by the British Museum (Natural History) in 1935, while one introduced species mentioned in that list, the musk-rat, is now extinct. The status of some of the newer arrivals is still obscure, and in a few cases we depend on only one or a handful of records to indicate that they have spread from their original centre of dispersal.

Much harm has been done in the past by ill-considered attempts to acclimatise animals (including of course invertebrates, with which this article is not concerned) outside their natural range. The examples of the rabbit in Australia, the starling in North America and to a smaller extent the grey squirrel in England are too well known to need detailed citation. A more recent example, which threatens to be equally disastrous, is that of the mink (*Mustela vison*) in Iceland, where, as a result of escapes from fur farms, a spreading plague of this rapacious animal is steadily decimating the waterfowl in which Iceland is rich. At the lake of Thingvalla, according to Julian Huxley, they have destroyed three-quarters of the wildfowl population.

It is clear that there are major economic disadvantages in irresponsible or careless introductions of alien species, and there may also be minor inconveniences to local naturalists, but nevertheless the light that may be thrown on population dynamics by these semi-natural experiments makes it worth while to collect all possible information about them. The scientist should not, as certain keen herpetologists have been doing in the London area recently, scatter possibly undesirable amphibians about the accessible public sheets of water, but when this has been done or when animals have escaped from captivity and established themselves at large, it is of the greatest possible interest to follow their fortunes.

Three stages in the colonisation of a new country by an animal can be traced. In the first stage a small colony becomes acclimatised in one locality, and sometimes it gets no further—for example, the ferret on Mull, the Egyptian goose in Norfolk and the midwife toad at Bedford. The next stage sees the gradual spread of the animal over all types of country suitable to it, and this is the stage in which several of the introduced species of deer seem to be at present. Finally the species either occupies the whole area within its ecological range, as the rabbit and brown rat for instance have done, or exists over a wide area of country in a series of discontinuous populations which no longer appear to be spreading, as is the case with the goat and the Canada goose. Partly because of the incompleteness of our knowledge, not all the species discussed here fall neatly into one of these categories—the edible frog, for instance, has a disconcerting habit of dying out in one place and bobbing up elsewhere—but it will serve as a broad picture.

Among the new British mammals, no insectivores or bats appear to have been introduced, though it was not until 1924 that the existence of the Scilly shrew (*Crocidura cassiteridum*) was made known. It had evidently been there all the time, but had been overlooked. Fortunately no attempts have been made to acclimatise the larger carnivores in the British Isles, despite frequent suggestions that brown bears would make a welcome addition to the amenities of a national park in the Highlands. Two small carnivores may, on the other hand, be counted, the ferret (*Mustela furo*) and the domestic cat.

About 1934 polecat-ferrets (a fertile cross between the ferret and the polecat) escaped on the island of Mull and began to breed in some numbers, as many as twenty-two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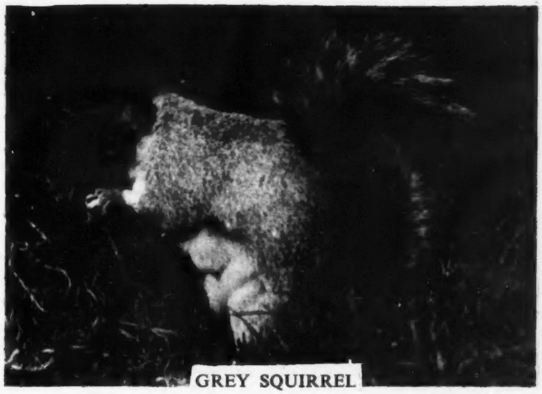
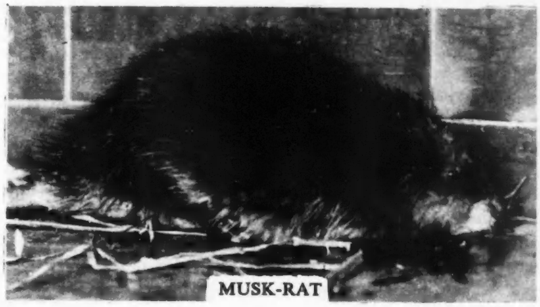
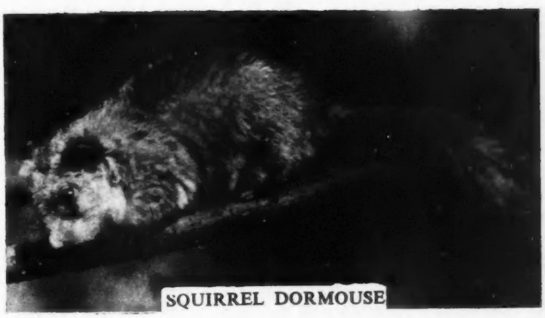

GREY SQUIRREL

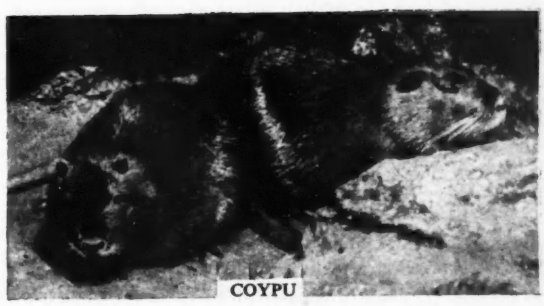
being bagged by one trapper in a single year; in 1947 Dugald Macintyre reported they were much reduced in numbers owing to disease. Ferrets have also been turned down on Harris to control the rabbits, and according to Seton Gordon have increased to such an extent as to have exterminated the ptarmigan population on Clisham.

Almost all the really destructive introduced mammals in the British Isles are rodents, and if we were rid of the house-mouse (*Mus musculus*), the black and brown rats (*Rattus rattus*, *R. norvegicus*), the rabbit (*Oryctolagus cuniculus*) and the grey squirrel (*Sciurus carolinensis*), most pest officers would become unemployed. The house-mouse does not really come within the ambit of this article, for though it is one of man's most widespread commensals, we do not know when it first arrived in these islands, and it may well have done so in the neolithic period. The presence of two alien subspecies of the house-mouse, *orientalis* and *gentilis*, has been reported in Ireland, both having occurred in Dublin and *orientalis* also in three other counties. The story of the invasion of the two rats, the black during the Crusades and the brown in 1728 or 1729, has been told many times. The brown rat is a universal pest, but the black rat is at present confined to docks and wharves and adjacent areas in certain seaports, though in London it also occurs in a wide area away from the docks. There are three colour-phases in the London black rat population, representing the types of good subspecies in other parts of the world, viz. *rattus* (blackish), *alexandrinus* (brownish) and *frugivorus* (pale-bellied). In London, however, they are all mixed up in one interbreeding population, with many intermediates.


MUSK-RAT


SQUIRREL DORMOUSE

Though there is still some dispute as to whether the rabbit existed in Britain between the end of the Ice Age and the Norman Conquest, it seems probable that our present infestation with rabbits stems from large-scale escapes from medieval 'coney' farms, whether or no there was a pre-existing wild rabbit population. The appearance of the grey squirrel is much more recent, dating only from the 1890's, but the rapidity with which it has spread over the country is shown by the map on p. 61. Edward Step, writing in 1921, stated that the chipmunk (*Tamias striatus*) had become acclimatised in the London area, but there is nothing further about it in the annals, and it has evidently died out. There is, however, good evidence that the bulk


COYPU

of the red squirrels of the Epping Forest area of Essex belong to the Continental race (*Sciurus v. vulgaris*), originating from a number released there in 1910 at a time when the native race had died out.

Two other introduced rodents are living in a wild state in England at present, and one has been exterminated. The fat, or squirrel dormouse (*Glis glis*) was introduced at Tring, about 1902, and has since spread over a radius of about fifteen miles. It has been reported from much further afield, but it is possible that there has been confusion with young grey squirrels. A useful distinction is the fact that the fat dormouse frequents roofs, attics and wainscots but the grey squirrel does not. Both the musk-rat (*Ondatra zibethica*) and the coypu (*Myocastor coypus*) escaped from fur farms between the wars and established themselves in marshy places, but thanks to a vigorous control campaign the musk-rat was wiped out by 1939 before it could do serious damage to any river system. The less harmful coypu still exists at large in such places as the broads on the Norfolk Yare and a sewage farm in the Thames valley near Eton.

Ungulates (hoofed mammals) have been kept so long by man for both economic and latterly also aesthetic reasons that it is not surprising to find goats and several kinds of deer among the new British fauna. There are herds of wild goats (*Capra hircus*) in many parts of Scotland and Wales, Snowdonia, the Pembroke coast, Arran, Bute and Inverness-shire, for instance, and also in England in the Lake district and Staffordshire. They must all be descended from escapes from medieval and later herds, and now lead a completely wild existence.

Few people realise that in addition to the three native species of red, fallow and roe deer, there are six other species, two of them in two races, at large in the woodlands of Great Britain. The fallow deer (*Dama dama*), like the rabbit, is a mammal whose credentials as a British native are suspect, but some wild herds, such as that in Epping Forest, are of considerable antiquity if not actually aboriginal. It seems fairly certain, however, that the feral fallow which are at present at large in almost every English county mostly originated as escapes from park herds. In southern England the roe-deer (*Capreolus capreolus*) also ranks as introduced, the present stock deriving from some put down in Dorset about 150 years ago. A subsidiary effort to reintroduce the roe into Epping Forest in 1883 throve for a time—there were thirty-six in 1901—but none have been seen for twenty-seven years. The most widespread of the wholly alien deer is the sika (*Sika nippon*), which occurs in most counties south of Lancashire and Yorkshire and in three places in Scotland. There are two races, the Japanese (*nippon*) and the Manchurian or Korean (*manchuricus*), which appear to be interbreeding freely. The alien deer with the most restricted distribution at present is the American black-tailed deer (*Mazama columbiana*), which is at large only in one small area of England.

Finally, there are four species of deer which have originated in Bedfordshire, having escaped from the Duke of Bedford's collection at Woburn or from Whipsnade Zoo a few miles away. These are the axis (*Axis axis*), which may be looked for anywhere within fifty miles of Woburn; the Siberian roe (*Capreolus pygargus*), which has been shot seventy miles away and is interbreeding with the native roe in at least one district; the Chinese water-deer (*Hydropotes inermis*), which stands only about twenty inches high and has been reported eighty miles from its point of origin; and the equally small muntjac or barking deer (*Muntiacus muntjac*), which has so far outdistanced all the others and reached Matlock in Derbyshire, a hundred miles from Woburn. Here again, two races have escaped, the Indian (*muntjak*) from Woburn and the tiny Chinese (*reevesi*), only fourteen inches high, from Whipsnade, and are evidently interbreeding as a hybrid has been shot. Most of what we know of the distribution of these alien deer is due to the researches of Gerald Johnstone, and to the collation by Sir William Taylor of information contributed by officers of the Forestry Commission, but much has still to be learned.

Turning now to birds, most of the introduced species have been here a long time and are well known. Some, such as the pheasant (*Phasianus colchicus*) and the red-legged or French partridge (*Alectoris rufa*) are game-birds, introduced for sporting purposes. P. R. Lowe has shown that there are no authenticated bones of the pheasant from British sites unquestionably contemporaneous with the Roman occupation, all he examined being those of the domestic fowl, and that there is no convincing evidence of the presence of the pheasant in prehistoric western Europe. It would therefore seem as if the bird must have been introduced into western Europe by the Romans and into Britain by the Normans, the first written reference occurring in 1059. This pheasant was the Caucasian race *colchicus*, the so-called 'old-English' pheasant. From the eighteenth century onwards various other kinds of pheasants, including the Chinese (*torquatus*) and Mongolian (*mongolicus*) races of *colchicus*, the Japanese pheasant (*P. versicolor*), the golden pheasant (*Chrysolophus pictus*) and Lady Amherst's pheasant (*C. amherstiae*) have been put down in English woods to enhance the bags of sportsmen. The present British pheasant population is therefore a complete genetic mixture, though the great majority of cock pheasants resemble either the *torquatus* or *colchicus* types. For a good many years after 1870 a colony of Reeves's pheasant (*Syrmaticus reevesi*) flourished at Guisachen, Inverness-shire, and the Duke of Argyll maintained wild turkeys (*Meleagris gallopavo*) at large in his woods at Poltalloch and Inveraray for some years during the last century.

The red-legged partridge was introduced during the seventeenth and eighteenth centuries and now occurs over the greater part of southern and eastern England as a perfectly wild bird. Its congener the Indian chukar partridge (*Alectoris graeca chukar*) has been acclimatised in various places, but rarely seems to stray far from its home estates. Unsuccessful attempts have been made to establish several other game-birds, including the Virginian colin (*Ortyx virginiana*) and the rufous tinamou (*Rhynchotus rufescens*), the latter surviving for several years in Essex in the eighties. Complete success, however, attended the reintroduction of the capercaillie (*Tetrao urogallus*) in Scotland from Swedish stock in 1837, after a number of failures.

The desire to embellish estates with ornamental waterfowl has led to the addition of the Canada goose (*Branta canadensis*) to the British list, the bird having lived a wild life in Britain for some two hundred years. The gadwall (*Anas strepera*), previously a winter visitor only, became

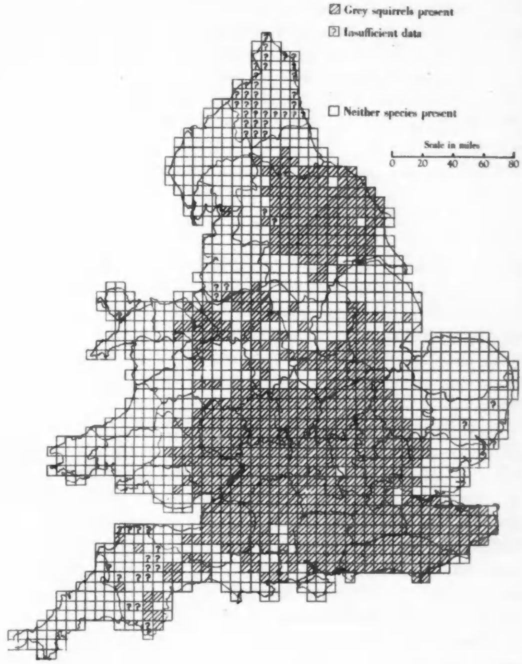
British breeding bird as a result of the offspring of pinioned birds being allowed their freedom in Norfolk in 1850 some years before genuine wild birds started to breed in Scotland. There is now also a small wild colony at Barn Elms, Surrey, originating from the offspring of pinioned birds in St. James's Park. For many years there has been a semi-wild colony of Egyptian geese (*Alopochen aegyptiacus*) at Holkham in Norfolk, and a pair reared three young in Hertfordshire in 1938. The mandarin duck (*Aix galericulata*) is very easy to acclimatise here and breeds locally in several places where there are or have been collections of ornamental waterfowl. The mute swan (*Cygnus olor*) does not strictly count as an introduced bird, as it must have existed in a wild state in parts of the country before the large number of descendants of domesticated birds which now abound on our lakes and ponds were able to establish themselves. Black swans (*Chenopsis atrata*) have frequented the Thames in London for many years and were also at one time resident on the Isis at Oxford, but are not recorded to have bred.

The introduction of the little owl (*Athene noctua*) by Lord Lilford in Northamptonshire in 1889 and by E. G. B. Meade-Waldo in Kent in 1896 was as capricious as that of the grey squirrel by the Duke of Bedford and others at about the same time, and the bird spread as rapidly as the mammal. The little owl now breeds over practically the whole of England and Wales, having reached Pembrokeshire in 1920, Cornwall in 1923 and Northumberland in 1935. The escape of numerous pigeons (*Columba livia*) from medieval and later dovecots in our towns has led to the remarkable situation (since the domestic bird is at present taxonomically indistinguishable from the rock-dove) that there are two very different ecotypes (i.e. populations of one species occupying different habitats) at large in the British Isles. The native rock-dove population inhabits sea cliffs and is only slightly dimorphic* (a small proportion have chequered plumage), and the escaped semi-domestic pigeon population lives in towns and is more polymorphic* and genetically mixed even than the rats and the pheasants.

Perhaps fortunately, few reptiles have been introduced, and none of them have spread far. The European pond-tortoise *Emys orbicularis* was introduced in two places in Surrey, at Shere in 1890–91 (two survived till 1906 when two more were added) and at Frensham a good many years ago, and it is possible that the three tortoises, all believed to be of this species, which appeared in various parts of Surrey in 1933–34 originated from one of these sources. Another terrapin, *Chelydra serpentina*, was released at Frensham at the same time and one of this species turned up at Shottermill, Surrey, in 1925. A third species of terrapin, *Emys lutaria*, was introduced at two places in Suffolk in 1894–95, was still there in 1908 and was found a few miles away at Snape in 1934. Green lizards (*Lacerta viridis*) have been introduced in several places and have survived at large for some years, but only in the Isle of Wight has one ever been known to wander far.

Among the amphibians, three species of frog have been introduced into England, and the common frog (*Rana temporaria*), in defiance of St. Patrick, was introduced into Ireland in the eighteenth century and has now spread all over the island. The edible frog (*Rana esculenta*) existed for many years in the Fens and elsewhere in East Anglia, having possibly been introduced to eke out the diet of French monks in the Middle Ages. It is now apparently extinct in East Anglia, but exists in several thriving colonies in the Home Counties (one of them on Hampstead Heath), some of which seem to have been established quite recently by amateur herpetologists. The marsh frog (*R. ridibunda*) has colonised the whole of Romney Marsh from twelve specimens from Hungary released at Stone-in-Oxney in 1935. As this frog is very noisy at night its introduction elsewhere cannot be recommended. The tree-frog (*Hyla arborea*) has been introduced in several places, but only in the Isle of Wight has it wandered far and bred elsewhere. A small colony of the midwife toad (*Alytes obstetricans*) has existed for many years at Bedford without showing any signs of spreading.

* A genetically variable species with two main forms is known as dimorphic, and one with more than two is polymorphic.



The distribution of the American Grey Squirrel in England and Wales. County boundaries and the 10-kilometre National grid are shown. The squirrel is present in shaded areas, absent from unshaded ares; its occurrence is doubtful in squares carrying a question mark. (*From Monica Shorten's paper on the distribution of Grey and Red Squirrels in "The Journal of Animal Ecology," May, 1946.*)

Enough has now been said to show that the subject is of the greatest interest to ecologically-minded naturalists, though I have had to omit many interesting examples of native British species introduced outside their natural range in the British Isles (for instance the mountain hare (*Lepus timidus*) in South Scotland and North Wales). It is also apparent that in many cases there is extraordinarily

interesting material for the geneticist too. Half a dozen cases have been quoted, of interbreeding of forms that could not occur in nature on account of geographical or ecological barriers (roe, muntjac and sika deer, black rat), of the injection of several different species and subspecies into one population (pheasants), and of the interbreeding in feral conditions of forms drawn out of the species' own gene-pool and bred true by man (semi-domestic pigeon). Here is a series of open-air experiments that are worth the while of geneticists to study closely.

The author is at present engaged in a full survey of the distribution of introduced terrestrial vertebrates in the British Isles, and will be grateful for any unpublished record of the less well-known species.

(The photo of the Red-legged Partridge and the cover picture are by Eric Hosking; the remainder of the photos are copyright by the Zoological Society of London.)

FUTURE OF THE FLYING BOAT—*Continued from p. 57*

air history from 1936 up to the outbreak of the war. And, quietly, they did a grand job of work during the war, in which many of them were destroyed. Those that survived continued to fly a short time afterwards until they could be replaced by more modern aircraft. During these years they piled up millions of flying miles between them.

In 1934, Imperial Airways (forerunner of B.O.A.C.) gave an order to Short Brothers, then of Rochester, Kent, and now of Belfast, to design a four-engined flying boat. The 'C' class was the result. Then the Government introduced the Empire Air Mail scheme and the need for aircraft became greater, so the entire fleet of 28 Empire boats was ordered "off the drawing board", without a prototype even having flown. The confidence of the Government and of Imperial Airways was more than justified.

When they were introduced, the Empire flying boats were the last word in luxury air travel, and Imperial Airways built up much of their great reputation with them. Carrying twenty-four passengers and a crew of five, the 'C' class aircraft had a maximum speed of 200 miles an hour (about half the projected speed of the 'Princess') and cruised over the 'all red routes' at 145 m.p.h. They had a wing span of 114 ft. and were 88 ft. long.

'Canopus' made her first flight in October 1936. Then Alexandria was the farthest east the flying boats went, but a year later, after survey flights, the route was lengthened to Karachi. Things moved swiftly; a month later a 'C' class boat surveyed the route as far as Singapore, and within another month 'Centaurus' was on her way mapping out the route to Australia and New Zealand. The Empire air scheme was beginning. On June 26, 1938 the first through service was opened between Southampton and Sydney.

But a year before that, other Empire class flying boats had been pioneering the Atlantic. On July 5–6, 1937, 'Caledonia', piloted by Captain A. S. Wilcockson, flew from Foynes into Botwood in Newfoundland—1993 miles —in 15 hours, and on to Montreal and New York. It was a survey flight, but it proved that airliners could conquer the Atlantic. The United States were using flying boats also at that time. Simultaneously a Pan-American Airways 'Clipper' flew the other way. Before a month was out, 'Cambria' had followed 'Caledonia' and many more proving flights were made. It was not, however, until August 1939 that the first Atlantic air mail service was started by 'Caribou' and 'Cabot'.

In the meantime 'C' class flying boats had carried out the pioneer refuelling-in-the-air tests over the Atlantic, replenishing their fuel tanks from aerial tankers which went up to meet them over Foynes and Botwood.

While the Empire and Atlantic routes were being pioneered by aircraft of 'C' class, Short Brothers produced the Mayo Composite aircraft. Planned by Major Robert H. Mayo, then technical adviser to Imperial Airways, the composite was two aircraft, the seaplane 'Mercury' which was carried on the back of the flying boat 'Maia'. On October 6, 1938, 'Mercury' was launched from 'Maia's' back over Dundee and flew non-stop to South West Africa to establish a 5,998 miles long distance record for seaplanes. Four months earlier 'Mercury', carrying a payload of 1000 lb., made the first commercial crossing of the Atlantic by a heavier-than-air machine.

Launched from Foynes, 'Mercury' reached Botwood in 13 hours 29 minutes—the fastest crossing up to then.

From the 'C' class boats, Shorts developed the 'Sunderland' flying boats which, with R.A.F. Coastal Command, played such a big part in defeating the U-boats in the Battle of the Atlantic. So naturally from the more powerful wartime 'Sunderlands' sprang the more luxurious airliners that went into operation on the B.O.A.C. routes with the coming of peace. There were the 'Hythes' which were withdrawn only in February 1949 after three years on the Australian 'run' on which they flew millions of miles and carried a total of 31,000 passengers. A lot of the 'Hythes' are still flying; they were sold to Aquila Airways, a private charter company.

Then came the 'Sandringhams' and the 'Plymouths' (which varied from the Sandringhams only by having American engines instead of British) and finally the Solents. All these 'airboats' trace their ancestry directly to the fine old Empire boats.

Similar flying boats are in service with Tasman Empire Airways between Auckland and Sydney, a vital link in the Empire 'chain'. 'Sandringhams' are also used in Norway.

B.O.A.C.'s Atlantic service began its peace time operations with three ex-Pan-American Airways flying boats—Boeings—bought early in the war and used in the war for V.I.P. flights to and from the U.S. Mr. Churchill flew back home in one of them after the 1942 Washington conference with President Roosevelt.

These were later replaced by Lockheed 'Constellation' landplanes and are now being added to by Boeing 'Stratocruisers'—both American wheeled aircraft. Although the corporation are only just beginning to make delivery of the 'Stratocruisers' which should have a life of several years, those who have the British aircraft industry's interests at heart hope that it will not be long before they are replaced by British-built aeroplanes. And there are many who would like to see jet-engined flying boats as the replacements. They would be carrying on a great British sea/air tradition.

J. S.

Far and Near

Honours for Scientists

AMONG the scientists whose names appeared in the New Year's Honours List were Prof. A. C. Tansley, Prof. A. L Bowley, Mr. F. Brundrett and Dr. O. H. Wansbrough-Jones.

Prof. Tansley and Prof. Bowley received knighthoods. Tansley's name is familiar to all students of botany; his elementary textbook is widely used in British schools, while the extent to which British botany is concerned with the study of plant ecology is a tribute to the way in which Tansley has propagated his own special interest. The healthy state of this particular branch of botany in Britain owes more to Prof. Tansley than to any other individual. He was university lecturer in botany at Cambridge from 1906 to 1923, when he left to become Sherardian Professor at Oxford (1927–37). He was elected F.R.S. in 1915, and was awarded the Linnean Gold Medal in 1941. In 1902 he founded *The New Phytologist* which he edited for thirty years, while he was editor of the *Journal of Ecology* for twenty-one years. He is chairman of the Nature Conservancy and president of the Council for the Promotion of Field Studies. His books include: *Introduction to Plant Ecology* (1946), *Britain's Green Mantle* (1949) and *The New Psychology* (1920).

Prof. Bowley, who becomes a knight was professor of statistics at London University (1919–36) and acting director of Oxford University's Institute of Statistics (1940–44).

Mr. F. Brundrett, who is awarded a K.B.E., was appointed Chief of the Royal Naval Scientific Service in 1947, after a long career as a naval scientist.

Dr. O. H. Wansbrough-Jones (awarded a C.B.) is scientific adviser to the Army Council. A physical chemist, he used to be on the staff of Cambridge University's department of colloid science.

Einstein's New Theory

A NEW generalised theory of gravitation which seeks to offer an explanation of all physical phenomena, including gravitational and electromagnetic phenomena, is published this month in the later edition of Einstein's *The Meaning of Relativity* (Princeton University Press). Copies of the relevant new pages were released at the recent meeting of the American Association for the Advancement of Science, and prompted big stories in the lay press on both sides of the Atlantic though no informed comment on the theory had been published at the time this issue went to press. Einstein has himself made this remark about it: "Due to mathematical difficulties, I have not yet found a practicable way to confront the results of the theory with experimental evidence."

Neurotic Ants

IN a lecture to the Linnean Society of London on January 5, Derek Wragge Morley described how he had observed neurotic behaviour in one of a colony of large Black Ants (*Formica fusca*) whilst demonstrating to a friend how an ant runs through an experimental maze. This ant had just completed an experimental run in the same maze and had only been back again with its comrades in the observation nest for a few minutes. When it was put into the maze for the second time it started to show twitching movements of its feelers and legs. It soon started off to run through the maze, which it normally did in about forty to fifty seconds without making a single mistake. Unfortunately on this occasion, when it got halfway through, it hesitated and made a mistake. Its limbs and feelers twitched spasmodically while it kept on trying to get through the wall of the cul-de-sac. These spasmodic jerkings got worse as the ant became more excited, and it soon started to circle backwards while still showing bad twitching movements, and eventually

Prof. E. N. da C. Andrade, F.R.S., who has succeeded Prof. E. K. Rideal as director of the Royal Institution.

collapsed and became unconscious. This ant recovered when placed under a cold-water tap for a few seconds. Since then he had observed several cases of comparable breakdown in ants and found a variety of ways of producing this sort of nervous breakdown in these insects.

Fountain-pen Radiation Meters

COMMERCIAL production of 'fountain-pen' radiation detectors has now started in Britain, reports *Atomic Scientists News*, journal of the Atomic Scientists' Association. The instrument is a quartz-fibre electroscope, the scale reading of which is read visually by holding the 'fountain-pen' up to the light. The range is 0–200 milliroentgens. The instrument is said to be extremely robust, and waterproof, and will probably be useful to radiologists, workers using radioactive materials, and to A.R.P. personnel.

Better Prospects for Atomic Control, says A.Sc.W.

A STATEMENT issued in December by the Executive Committee of the Scientific Workers comes to optimistic conclusions about the prospects for agreement being reached on a scheme for the international control of atomic energy. It also argues that the situation is improved because the Russians have found the secrets of atomic-bomb manufacture.

The document points out that the chief difference between the majority and the minority in the United Nations concerns the proposals for control and inspection. Those supported by the U.S.A. and Britain ask that ownership and management should be in the hands of the United Nations. The Russian proposals reject the idea of international ownership and management and in requiring only periodic inspections and special investigations instead of having a permanent roving commission with the right to go anywhere they choose at any time.

Previous Anglo-American objections to the Soviet proposals were that they might enable her to obtain access to secret American technical information essential for the production of atomic energy, and then use it to produce atomic weapons in secret factories not thrown open to inspection by the Atomic Energy Commission of the United Nations. "Since it has now been revealed that the Soviet Union had solved the main problems of the manufacture of atomic explosives in 1947, these objections have less importance. We believe that if United Nations inspectors were allowed equal access to both Soviet and American atomic establishments and those of all other nations), this would constitute a very considerable step towards the institution of a watertight control scheme," says the A.Sc.W.

The statement concludes by putting forward two suggestions "which might provide the basis for a settlement of this important problem". Firstly, the A.Sc.W. proposes national ownership, production and distribution of fissile materials should continue but there should be installed a permanent commission or inspectorate of the United Nations at every plant, the personnel of which should have access to all information necessary to record the production of all fissile materials and the use to which they are put. This inspectorate would be charged with the responsibility of reporting to the Atomic Energy Commission of the United Nations.

Their second point is that existing stocks of bombs should be dismantled under United Nations supervision within an agreed period after the signing of the Convention requiring the immediate establishment of the machinery of inspection.

* * *

Gallup public opinion polls show that the majority of British and American people think that war is more likely now Russia has the know-how of atomic

bomb manufacture. The results of both polls were published in the *News Chronicle* (January 9, 1949).

A Guide to Science Reading

THE Science Masters' Association has prepared a new edition of the booklet *Science Books for a School Library*. It contains valuable lists of volumes dealing with astronomy, biology, chemistry and physics, while there is a useful reading list for general reading in the history of science and biography and also a list of applied science books. For each work it is indicated whether it is suitable for young students or only sixth formers. There is, however, no indication of the relative merits of the books listed, but references are given so that it is possible to trace the critiques of those works reviewed by *School Science Review*.

Quite apart from its use in schools, this booklet can be recommended to anyone with a wide interest in science who is in need of a guide when using the bewilderingly large collections of science books which quite average public libraries have by now accumulated. It costs 3*s*. and is published by John Murray.

Electrical Engineering Training

ONE of the largest electrical engineering companies in the country, English Electric Company, has training schemes for several classes of apprentices and students in all branches of engineering. There are three main groups of trainees. Craft apprenticeship is open for young men who show the ability to become skilled craftsmen, and normally involves five years training. Candidates for the second group of student apprentices must have obtained a good School Certificate with credits in mathematics and science. The object of this course is to train young men for junior staff positions in the drawing office, the works, or on the engineering, erecting or commercial staffs and is open to students of 16–18 years. The course lasts four years.

A graduate training course is open to young men who have a degree or an equivalent diploma in engineering, or an honours degree in mathematics or physics, of an approved university or training college. The course lasts two years. Candidates for training from overseas must normally qualify for this graduate apprenticeship. A brochure describing the apprenticeship schemes can be obtained from: Central Personnel Services, English Electric Company Ltd., 24–30 Gillingham Street, London, S.W.1.

Streptomycin Safeguard

STREPTOMYCIN can now only be manufactured for sale in the United Kingdom under licence and it must conform with prescribed conditions as to strength, quality and purity. These requirements are laid down in the Therapeutic Substances Amendment Regulations, 1949, and are designed to safeguard the public against the sale of inferior and possibly dangerous preparations.

Explosion Risk with Ammonium Nitrate

FOLLOWING the disasters at Texas City and Brest when ships loaded with ammonium nitrate fertiliser caught fire and exploded, an inquiry was made by Britain's Armament Research Establishment into possible hazards with British grades of this material.

The material which exploded at Texas City and Brest consisted of ammonium nitrate specially treated for use in agriculture. Ammonium nitrate cakes into a relatively solid mass very soon after manufacture and in order to keep it in a free flowing condition the American product is coated with about 1.0% of vaseline and about 5% of kaolin. It is packed in 100-lb. six-ply paper bags, two of the layers being treated with an asphaltic compound.

The British material used in agriculture is packed in 4-cwt. steel drums. Sometimes the drums are lined with waxed-paper. The ammonium nitrate, prepared synthetically, is of a high order of purity, containing 99·8% ammonium nitrate.

The investigators first studied the differences in behaviour when the materials are subjected to heat.

Early experiments conducted purely on the laboratory scale showed the American grade to be less stable than the British. These were followed by large-scale trials, intended to reproduce the conditions under which a fire would actually develop in a ship's hold. These were carried out in a concrete bunker and in two steel lighters.

The experimental fires each involved roughly 40 tons of ammonium nitrate, 2 tons of chopped wood and 4 tons of wood mixed with ammonium nitrate. The last two items were used to start the fire.

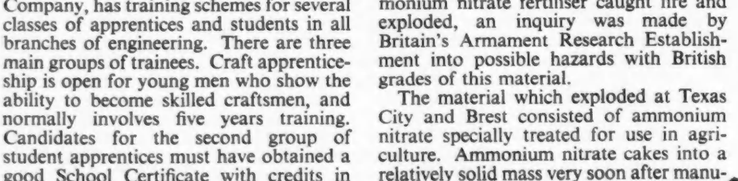
These tests showed that when *pure* ammonium nitrate is strongly heated it decomposes with evolution of gas, and if the nitrate is confined in a closed container the pressure developed may eventually burst the container. But even with strong confinement, the decomposition of the salt does not develop into a true explosion. Furthermore, paper bags or wood choppings mixed with the fertiliser also did not promote explosion. Thus there is no risk in using unbituminised paper bags or waxed paper linings for steel drums.

The other important discovery was that the presence of 1% of vaseline led to very different results, for with strong confinement such a mixture tends to become explosive.

An Ancient Eskimo Civilisation

THE remains of an ancient Eskimo civilisation have been found on Cornwallis Island by Dr. Henry B. Collins of the Smithsonian Institution and J. B. Michea of the National Museum of Canada. Cornwallis Island lies to the north of Alaska (long. 95°, lat. 48°). About half of the Canadian arctic islands are now occupied or occasionally visited by Eskimos but there has so far been insufficient exploration of these regions to tell how far they were inhabited in the past. The Cornwallis discoveries are of ruins of permanent houses (as shown in the picture) with stone walls and floors and roofs of stones, whale bones and turf. The Eskimos evidently depended on the bowhead whale, seals and walrus for their food, supplemented by caribou, polar bear, foxes, muskox, birds and fish.

Harpoon heads, implements and weapons carved from bone, walrus ivory and caribou antler, and articles of wood, stone, baleen, skin and feathers have been found. The disappearance of the bowhead whale from the waters of the Arctic Archipelago probably accounted for the Eskimos' desertion of the island. Whether they migrated into Greenland or south into Canada cannot be determined until the collection made on the expedition has been examined in detail.



Ruin of ancient Eskimo house on Cornwallis Island.

The Bookshelf

Radio Frequency Heating. By L. Hartshorn. (London, Allen & Unwin, 1949; pp. 237, with 13 tables and 102 illustrations, 21*s.*)

THIS book is said to have been written as a result of the author's lectures to various groups of people interested in radio-frequency heating, including biologists, metallurgists and chemists as well as engineers and physicists. But one feels that only the latter two groups will appreciate the theoretical chapters, since quite advanced electrical theory is involved.

The applications of high-frequency induction heating to the local heating of metals (e.g. for case-hardening of gears or the soldering of seams in tin cans) are by now fairly well known, but the applications of dielectric heating are of infinite variety. One may not feel much sympathy over the engineer's difficulties in preparing blocks of dehydrated cabbage, but one feels a very real interest in the study of the behaviour of the fat and lean parts of a whole ham when subjected to r.f. heating, and the idea of using centimetre radio waves to turn a cold morsel into a hot dog in two seconds sounds just right for the American drug store. More seriously, however, dielectric heating has been applied to the quick setting of glued wooden structures, pre-heating of plastic blanks for moulding, welding of thermoplastic materials and drying of penicillin. The author gives a very fair picture of the economic balance of its high cost *versus* the time-saving and controlled heat-distribution features of heating, and the book can be recommended to any engineer who is thinking of building or installing this type of equipment, and to the student of electrical engineering.

D. A. BELL.

Haemoglobin. Edited by F. J. W. Roughton and J. S. Kendrew. (London, Butterworth's Scientific Publications, 1949; pp. 317, 40*s.*)

SIR Joseph Barcroft worked for over thirty years on haemoglobin and at the end of World War II he had stimulated wide interest and research in this vital respiratory pigment. The workers on this subject foregathered periodically for discussion; when Barcroft died suddenly in March, 1947, his colleagues decided that the next meeting should be made a special one in his honour and it was held at Cambridge from June 15 to 17.

The book is based on the papers read at that conference and the early part records the biographical tributes paid to Sir Joseph at the beginning of the meeting. The rest of the book contains papers of a highly technical character dealing with such subjects as the structure of haemoglobin, reversible reactions of haemoglobin with oxygen and carbon monoxide, physico-chemical and biological and physiological aspects of haemoglobin and so on.

Many of those who are not specially interested in haemoglobin are interested in Sir Joseph Barcroft, and it warms the heart to read the tributes paid to this loveable personality by his friends and colleagues in the first twenty-six pages of the book.

GEOFFREY H. BOURNE.

Snowdonia. The National Park of Wales. By F. J. North, Bruce Campbell and Richenda Scott. (London, Collins, The New Naturalist Series No. 13, 1949, 469 pp., 21*s.*)

As the first of a new series of regional volumes, this book should not fail to arouse the interest of all lovers of the open air, in this century-old tourist centre, soon to become our first National Park. The three sections of the book are concerned with geology, natural history and historical background respectively, and the authors are to be congratulated on effecting a pleasing synthesis of these three aspects into a logical and fascinating story.

Dr. North's tracing of the events leading to the shaping of Snowdonia cannot help but stir all but the dullest of imaginations, and his clear and simple exposition of the underlying geological principles should ensure no loss of enjoyment by the most unscientific readers. In parts, however, descriptions of the structure of a succession of mountains and lakes becomes a little tedious and bring with them an unfortunate flavour of the guide book. Very little attention is paid to soils, a serious omission.

Dr. Bruce Campbell, in his survey of the natural history of the area, has divided it into natural zones, e.g. alpine, grassland, etc., and concerns himself mainly with descriptions of plant and animal communities in those zones. Where possible, both English and Welsh names are given for the species mentioned in addition to their scientific names. It is difficult, however, to see why in the plant lists in the appendix, and frequently in the text, details of species should have been omitted from certain genera, e.g. *Juncus*, *Carex* and the larger genera of the Gramineae, particularly as these genera play such an important part in the flora of the area. A little more attention could have been paid to the ecology of the zones considered, but proper prominence is given to the effect of man on the natural communities. Reference to the recent valuable work of the Welsh Grassland Survey throws much light on to these interrelationships. Much of the section, however, is written as an itinerary in the first person, giving the reader an unfortunate impression of superficiality, conflicting with the writer's obvious familiarity with the works of the early naturalists.

In the third section, Dr. Scott, outlines the history of the area from the earliest traces of human occupation to the present day. Quite apart from its value in elucidating the evolution of the present human communities, it will give to the majority of non-Welsh readers a glimpse of that part of British history which is all too unfamiliar.

The photographic illustrations, both in monochrome and colour, are of the usual high standard of excellence of this series but there is evidence of an unfortunate haste in the proof reading. In the first twelve pages alone there are four errors in references to plates and later in the book two plates are without numbers and captions. It is unfortunate that an otherwise excellent production should be marred by such carelessness.

L. J. AUDUS.

Magnetism. By David Shoenberg (London, Sigma Books, 1949; pp. 216, 10*s.* 6*d.*)

MOST of us have, at some time in our lives, been fascinated by the magic forces of attraction and repulsion between magnets, and many must have felt that they would like to know more about this subject. For those people, this new volume in the Sigma series affords an excellent opportunity to get an up-to-date account of this subject which plays a very important role both in fundamental research and in the field of technology.

Dr. Shoenberg is well known for his research on magnetism and on the very interesting physical phenomena which occur at very low temperatures. In this book he attempts more than simply to acquaint the reader with the laws of magnetism and its importance in everyday life. He tries to convey the basic aim of science, which is to understand and be able to predict as many phenomena as possible with the least number of necessary assumptions, and he also shows how scientists often achieve this aim in an indirect way. By probing into the laws which govern the minute forces of paramagnetism and diamagnetism, they have succeeded in unravelling the much more important but also far more complicated forces of ferromagnetism.

The first half of the book deals with the fundamental laws of electromagnetism and explains the magnetic properties of matter as a consequence of their 'atomic structure' and the various ferromagnetic properties as a consequence of their 'domain-structure'. One chapter is devoted to the earth's magnetism; a field more suited to speculation than experimentation. In the chapter dealing with magnetism as a tool of science the important part which magnetism plays in those giant machines such as the synchrocyclotron which have become essential in nuclear research is described.

The book, which is extremely well written and illustrated, can be highly recommended to the reader with some basic scientific background.

P. POPPER.

An Introduction to Botany. With special reference to the flowering plant. By J. H. Priestley and Lorna I. Scott. (London, Longmans, 1949; 2nd edition, 625 pp., 21*s.*)

FIRST year University students seek especially for facts and for inspiration.

The facts give substance to their studies, the inspiration enlivens the facts and stimulates the student to continue beyond the introductory stage. Any beginner who uses the new edition of Priestley and Scott will find there a rich store of facts. If he co-operates with the authors by observing plants and thinking about them, he must catch some of the inspiration so evident in the text of this excellently illustrated book. The authors have not hesitated to speculate beyond their evidence. This increases the stimulative value of the book, for facts without some dreams make for dullness.

The reader is encouraged to make the flowering plant the chief subject of his study. This introduces the beginner to botany at its most complicated level, but by starting with the plants which seem most familiar, and by touching more lightly on the lower plants, which beginners in botany often find surprisingly difficult, the authors are likely to gain the confidence and sharpen the interest of their readers. By no means all teachers of botany favour this method of approach, some preferring to start at the bottom and follow what purports to be an evolutionary sequence. Consequently, anyone who proposes to use the book in preparing for an examination should determine how far it fits the syllabus he has to follow. But, examinations apart, no reader can fail to learn a great deal of botany from Priestley and Scott.

B. BARNES.

Cathode Ray Tube Traces. By Hilary Moss, Ph.D. (Published by *Electronic Engineering*, London, 1949, pp. 66, 10*s.* 6*d.*)

"He studied electrons with vigour;
An oscilloscope's use was de rigeur.
But his poor mind was maimed;
Saw a girl and exclaimed,
'What a beautiful Lissajous figure'."

This rhyme (published in *Electronics* of July 1949) is inevitably brought to mind by Dr. Hilary Moss's book on *Cathode Ray Tube Traces*, which contains a large selection of Lissajous figures. Surely our grandparents who found interest in Lissajous figures produced by reflection of light off two tuning forks would have been thrilled by the beauty of some of these same patterns produced in colour on the cathode ray tube, and of others of Dr. Moss's patterns produced by circular and spiral scans of the tube with superimposed waves and by modulated waves. However, the modern engineer is not usually susceptible enough to meet the fate of the young man described at the head of this paragraph, and may be more thrilled at the precision of measurement which can be obtained with the patterns and the fact that Dr. Moss's book includes full circuit diagrams and mathematical theory of the equipment needed to produce the patterns.

A Class Book of Physical Chemistry. By Lowry and Sugden. (London, Macmillan, 2nd edn., 1949, 454 pp., 8*s.* 6*d.*).

LOWRY and Sugden is a minor classic in its field, often found useful even by senior workers for reference to some elementary fact or principle they find they have forgotten.

In this second edition, Prof. Sugden claims that nomenclature of the sections on elementary thermodynamics has been altered to conform with modern usage. Several important conventions, however, have not been altered. For instance, in a reaction which involves a heat change, the old convention was that evolution of heat was represented by a positive sign, and absorption of heat by a negative. Precisely the opposite convention grew up between the wars—and furthermore was codified in B.S.S. 813 in 1938—that evolution of heat represented a loss of energy by the system; it was therefore to be represented by a separate symbol—ΔH (at constant pressure) or ΔV (at constant volume)—and a negative sign. This has still to be given effect in 'Lowry and Sugden'.

The International Unions of Physics and of Chemistry have now agreed to abandon the calorie in favour of the joule as the more accurate and reproducible unit in calorimetry. This point will need to be met in any future edition of this book.

These are minor matters however, and the book remains a valuable introduction to the subject.

J. B.

Alcohol. A Fuel for Internal Combustion Engines. By S. J. W. Pleeth (London, Chapman & Hall, 1949, pp. 259, 28*s.*).

BEFORE the war most people were familiar with blended motor fuels such as "Ethyl" and "Benzole" mixtures, and the present volume recalls those days by setting out the case for ethyl alcohol used as an ingredient of motor spirit.

It opens with a very brief survey of the sources of energy available to man, stressing the important requirements of low cost, ready availability and high efficiency. This is followed by a condensed account of the production, synthesis and purification of ethyl alcohol including a fairly lengthy section on azeotropic distillation processes which are discussed in greater detail. Methanol and some of the higher alcohols are dealt with very briefly in the same chapter.

The bulk of the book presents and discusses the results obtained when various fuels are tested in I.C. engines, comparing normal petrol with blended spirits containing alcohol and benzole when used under a variety of conditions with special reference to such important topics as startability, vapour lock, engine knock and knock rating.

The book is not very well balanced and has a tendency to repetition, for example, the statement that "about 70% of all the motor spirit used in the world contains tetraethyl lead", appears no less than four times. The volume is essentially one for the fuel technologist who, however, will find much useful information collected together and illustrated by numerous tables and graphs. The case for and against the use of alcohol is fairly stated, and the book summarises much of the relevant research done in the last twenty-five years.

JOHN L. WALPOLE.

Achievements of Modern Science. By A. D. Merriman. (Gregg, London, 1949, pp. 272, 220 illustrations, 21*s.*)

THE title of this book is to a certain extent misleading. It suggests that one will find within a popular account of the more recent and spectacular advances in physics, chemistry and biology. What one does find is something very different. One is treated to a series of brief but highly concentrated courses of instruction on those branches of applied physics in which Dr. Merriman has special knowledge and experience.

The book opens with a thirty-seven page treatise on rockets which sets the pace for the remaining chapters—and a cracking pace it is. The present state of rocket development leads to a discussion of the requirements for space travel which, by referring to the possibilities of a space rocket with an atomic drive, clears the ground for a chapter on atomic energy. This, in addition to explaining the periodic table, isotopes, X-rays, the mass spectrograph, the cyclotron, the Geiger counter, the atomic pile and the atomic bomb, introduces the reader to the electron. In the following four chapters a good account is given of the principles of various electronic devices, including thermionic valves, the cathode-ray tube, radar instruments and the electron microscope.

The last three chapters of the book deal with rather unrelated subjects. The first of these deals with the earth's magnetism, magnetic mines and degaussing; the second, on the development of the aircraft propeller, contrives to impart quite a bit of aerodynamic theory. The final chapter, almost unexpectedly, is on the subject of weather control.

Before making his final assessment of a book a reviewer must ask himself how well it fulfils the purpose for which it was written. That question is difficult to answer. It is clearly not a book of reference, nor is it a popular exposition. Is it perhaps directed at people in other branches of science who would wish to know what the applied physicists have been doing recently? This may be near the mark; yet one hesitates to believe that the average biologist, for instance, would either wish to know or be able to retain as much as this book tells him about rockets. To anyone with some knowledge of the subjects dealt with it is evident that the author has done a masterly job of condensation and compression—but precisely for whose benefit is another question.

R. P. H.

Printed and Published in Great Britain by Jarrold & Sons, Ltd., Norwich. *Editorial Offices: 244 High Holborn, W.C.1.*

EDUCATIONAL ANNOUNCEMENTS

Space may be reserved in this section by scientific organisations, schools and colleges for announcements of courses, appointments vacant, etc.

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